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CONTENTS

ERRATA

Figure 5: In the legend "oi" should be "of" and "tounting" should be "counting."
Page 12, line 16: "observtaions" should be "observations."
Page 22, 9th line from bottom of page: "Morain Creek" should be "Moraine Creek."
Page 28, table 3: In the box head over the reading column the word "cubic" should not occur.
Page 52, table 17: "Decigrams" in the box heads should be "Hectograms."
Page 56, table 21: "Decigrams" in the box heads should be "Hectograms."
Page 309, last line: "on" should be "no."
Page 353, line 13 from the bottom: "athoms" should be "fathoms."
Page 409, first line of last paragraph: "severa" should be "several."
Page 473, last line of text: "orm" should be "form."
Page 495, line 4: "in" should be "is."
Page 540, line 3: "noe" should be "none."
Page 579: Below table 24 there should be a footnote, as follows: "See footnote 3, table 20, page 575."

INVESTIGATIONS CONCERNING THE RED-SALMON RUNS TO THE KARLUK RIVER, ALASKA

By CHARLES H. GILBERT and WILLIS H. RICH

CONTENTS

INTRODUCTION

The history of the Alaska salmon industry, until within the last few years, has been one of consistently increasing exploitation without regard to its effect on existing salmon supplies. In every district, as salmon stocks dwindled under this régime, the intensity of fishing effort was redoubled, and the amount of fishing gear in operation was increased by leaps and bounds in the attempt to maintain unimpaired, or to increase if possible, the size of the commercial pack. The necessity of making provision for future runs was ignored. No attention was given to the number of spawning fish that succeeded in escaping the nets. No one concerned himself with the size of the spawning reserves or their adequacy to maintain the runs. The congressional regulations in effect were hopelessly inadequate and the Bureau of Fisheries was without power to act.

Such a system could have only one result—the eventual depletion of the salmon supplies and the final extinction of the industry. This result was clearly foreshadowed in the years succeeding the close of the Great War and had been hastened, doubtless, by the extraordinary efforts during the course of the war to increase the salmon pack to the utmost, as a patriotic duty. Be that as it may, the conviction became universal, in the years following the armistice, that the salmon industry, by the methods then employed, was courting complete disaster and could be saved only by being subjected to close supervision under well-devised regulations.

To meet this emergency, Congress in 1924 enacted a law for the protection of the fisheries of Alaska, in which very wide regulatory powers were conferred on the Secretary of Commerce for the purpose of preventing further depletion of the salmon runs and of restoring them as nearly as possible to their former condition of abundance. Under his direction the Bureau of Fisheries has grappled with this problem.

Fortunately, considerable progress had been made prior to 1924 in ascertaining important facts in the life histories of our salmon. It was known that there are

five distinct species of wide distribution throughout Alaska, and that each of these species has an independent, self-perpetuating colony in each of the streams that it inhabits. Each colony forms a self-contained unit, the members of which consistently interbreed, their progeny returning to their native stream at sexual maturity. Such a colony secures no recruits from adjacent streams; its maintenance at a high stage of abundance depends on there being provided each year, from its own members, an adequate spawning reserve, which shall successfully deposit their eggs in the river gravels. This necessity defines in large measure the regulatory duties of the Bureau of Fisheries. It must counteract the destructive agency of an unrestricted fishery by adopting and enforcing such regulations, locally applicable to the different fishing districts, as will insure year after year adequate spawning in each of the multitudinous streams throughout the vast extent of Alaska. The magnitude of this problem becomes at once apparent, but its almost incredible difficulties are known only to those intrusted with the administration of these fisheries.

In the first place it must be ascertained whether depletion of a given salmon run has occurred, and if so, to what extent. With adequate and reliable statistics, extending over a sufficient period of time, this can be done. Annual fluctuations in the magnitude of the runs, due to natural causes, can be recognized and evaluated and a trend established that will measure the declining supply. Usually the salmon statistics of the past have been inadequate and more or less untrustworthy, but such as they are they form our only basis for establishing the fact of depletion and its extent. In cases of pronounced depletion, however, such as unfortunately exists in many localities, even the rudest statistics are sufficient to demonstrate its existence.

It remains, then, to apply the remedy, and the question at once has arisen of how extensive a spawning reserve must be provided to check depletion and increase the size of the colony. In all fishery investigations in which conservation of a threatened supply has been the principal aim, the ideal has been properly emphasized to spare for commercial use all fish not needed to maintain the fish population at a high level of abundance. It is a generally accepted motto that we limit our spawning reserves to the lowest numbers consistent with safety, sparing every fish that can be spared for the world markets and for human consumption. But at the time the responsibility for the salmon fisheries of Alaska devolved on the Secretary of Commerce and the Bureau of Fisheries, we were without definite information concerning the number of spawning salmon necessary to produce a run of a given size. It was not even known, with regard to any stream, what proportion of its run had constituted its actual spawning reserve in any year, whether adequate or inadequate. Such statistics as we had dealt invariably with the portion of the run that had been captured for commercial purposes, never with that moiety that had escaped the fishermen and formed the basis for expectation of future runs.

In default of this essential knowledge, which it requires years of investigation to obtain, it may be asked what in the meantime has formed the basis of the bureau's activities in protecting the various runs. The answer is, the method of trial and error. When it is believed that a given district is threatened with overfishing, regulations are enforced which will diminish the commercial take of fish and increase the size of the spawning reserve, and the severity of the restrictions is planned to bear a direct relation to the seriousness of the depletion. In such cases it is not known what

had been the size of the spawning escapement previous to imposing the restrictions. It was known merely that it was inadequate and that the situation would be improved by such increase as the restrictions would provide. Future observations would reveal whether the regulations adopted would prove adequate, or should be strengthened to permit an even larger spawning reserve. In the present state of our knowledge, it is by this method that the majority of the fishing districts in Alaska must of necessity be administered.

It had been realized, however, even prior to the enactment of the Alaska fishery law of 1924, that our ignorance concerning the size of an optimum spawning reserve constituted a serious handicap in the administration of the salmon runs, and a program of investigation had been adopted in 1921 with the purpose of obtaining the desired knowledge. Such an investigation must of necessity concern itself with the independent colonies of one or more individual streams, and these streams must be carefully selected with certain requirements in view. As the essential part of the problem is to ascertain the complete returns from spawning colonies of known size, the streams selected for investigation must be so situated and of such character that both that portion of the run taken for commercial purposes and the portion that escapes to the spawning grounds can be accurately enumerated year after year. None of the streams in southeastern Alaska fulfill these requirements, as their colonies on their spawning migrations traverse long waterways behind the islands, where they mingle with other colonies bound for different streams and in common with them are there subject to capture. The spawning reserve in each of these streams could be enumerated, but the commercial take belonging to any stream is hopelessly commingled with the product of other rivers. For the same reason, none of the highly important salmon streams in Bristol Bay lends itself to this investigation. The commercial takes of the various streams can not be segregated. For similar reasons, the streams that enter Prince William Sound and Cook Inlet are not eligible.

It had been decided to inaugurate the experiment with the red or sockeye salmon (*Oncorhynchus nerka*), partly because this species is the best known in its life history and partly because, as the most valuable species in Alaska and the most sought after, it is subject to a very intensive fishery and is in special need of protection. Two of the best-known red-salmon streams in Alaska are the Karluk River, on Kodiak Island, and the Chignik River, which empties on the southern shore of the Alaska Peninsula, near its base. Each of these streams has supported an intensively conducted fishery over a long term of years, and each of them still maintains a red-salmon run of importance, however it may be diminished from its primitive abundance. Both the Karluk and the Chignik Rivers are of such size and character as to permit the installation of counting weirs for enumeration of the spawning escapement; and, what is equally important, their runs are nowhere subject to any considerable commercial capture except in the vicinity of their respective mouths. Except for an insignificant number of stragglers, the Chignik red salmon are not subject to capture beyond the confines of Chignik Bay, while the Karluk fish are captured only on the beaches between Karluk Head and Uyak Bay, with a limited number in Uyak Bay itself. Both of these streams answer admirably the requirements essential for these investigations—their commercial take can be

completely enumerated, free from admixture with the output of other rivers, and their spawning escapements can be led through the gates of counting weirs and the numbers accurately ascertained. For this reason they have been selected for this experiment. A counting weir was first installed in the Karluk River in 1921 and in the Chignik River in 1922, and they have been maintained in each subsequent year. The present report deals with the results thus far obtained in the Karluk River, leaving for later consideration the parallel series of determinations in the Chignik watershed.

KARLUK RIVER WATERSHED

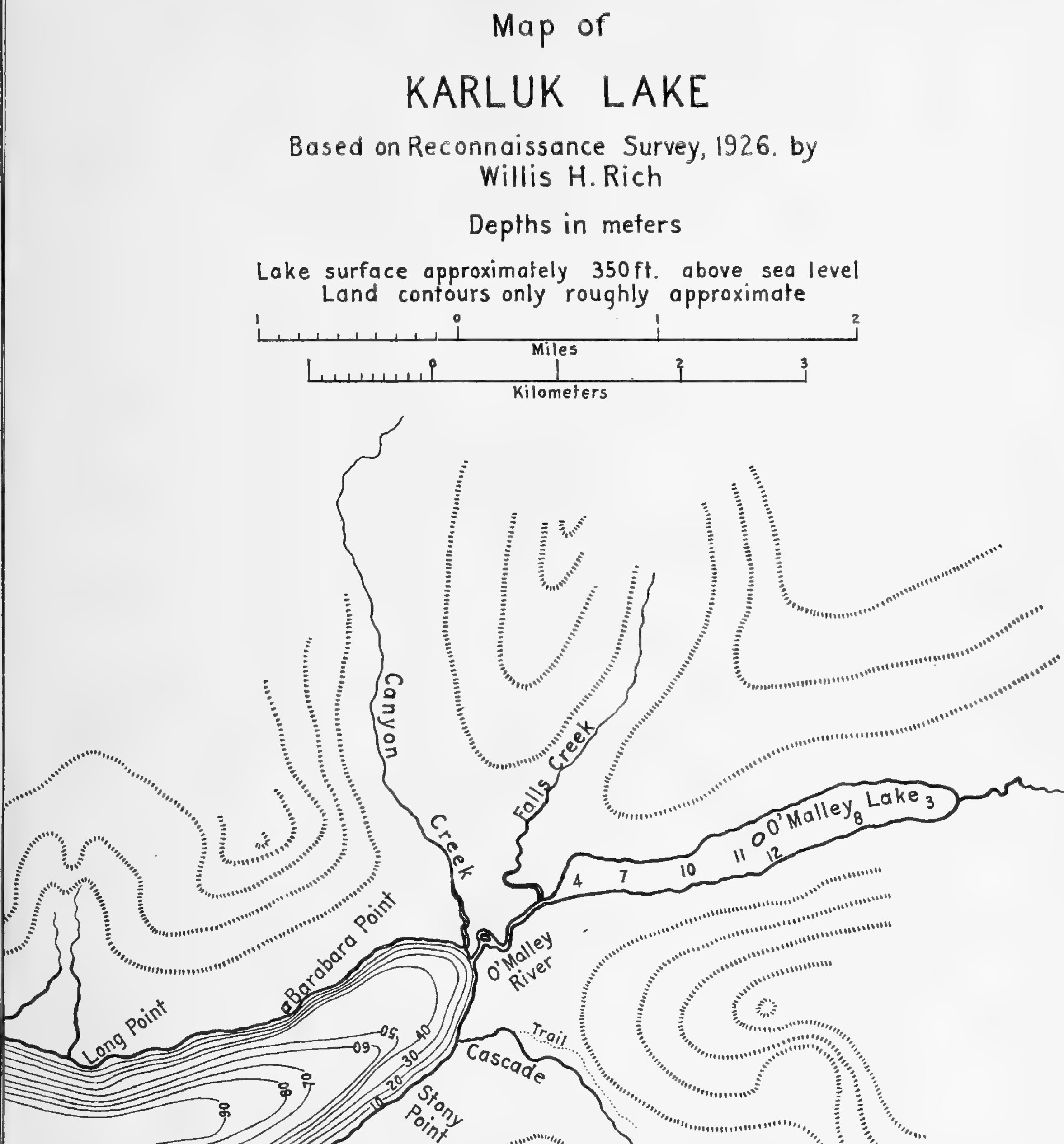
Karluk River and the lakes from which it takes its source are located in the western part of Kodiak Island, approximately 154° west longitude and between 57° and 58° north latitude. The outlet of the river, which is approximately 30 miles long, is into Shelikof Strait, a short distance east of Karluk Head, one of the most distinctive and conspicuous landmarks of the Alaska coast.

The lakes are situated about 350 feet above sea level, as determined by an aneroid barometer, and are three in number. The largest lake, Karluk Lake proper, is 12 miles long by 2 miles in width at the widest place, and the area is approximately 14.6 square miles. It extends almost due north and south, with the outlet at the northern end. There are two smaller lakes (Thumb Lake and O'Malley Lake [1]) above the main lake. The accompanying map (fig. 1) shows these lakes, the main tributary streams, and the depth contours, as determined by a reconnaissance survey made by sextant and plane table during the summer of 1926. The lake is surrounded by mountains that rise abruptly to a height of about 2,500 feet above the level of the lake, and most of the tributary streams drop down abruptly from these mountains, tumbling over bowldery beds, which appear to be anything but favorable spawning grounds. From a few hundred yards to a mile or so of the lower courses of these streams is accessible to the spawning salmon, but their ascent usually is stopped abruptly by insurmountable falls.

Upper Thumb River (above Thumb Lake), Canyon Creek, and Falls Creek are the largest streams of the system. They meander for some distance through comparatively wide valleys and offer apparently by far the best spawning conditions. The underlying rocks are almost entirely shales, with an occasional small ledge of quartz. In the absence of any calcareous rocks, the water is extremely soft (a sample analyzed through the kindness of Dr. E. A. Birge, of the University of Wisconsin, indicated only about 4.5 cubic centimeters of fixed carbon dioxide per liter). The basin is evidently of recent glacial origin, as is indicated by the numerous cirques to be seen on the mountains, by the distinctly U-shaped contours of the valleys, including the bottom of the lake, and by numerous fine examples of glacial erosion to be seen on the exposed bedrock along the streams. Karluk Lake proper evidently was made by the formation of a large terminal moraine at what is now the foot of the lake.

The lake is of such recent origin that the shores have been very little modified by the action of the streams that enter the lakes. In only a few places has the shore line been built out by the deposit of silt and bowlders from the mountain sides,

[1] Named in honor of the present Commissioner of Fisheries, who has done so much to further the study and scientific care of the salmon fisheries of Alaska.



Map of
KARLUK LAKE
Based on Reconnaissance Survey, 1926. by
Willis H. Rich
Depths in meters
Lake surface approximately 350 ft. above sea level
Land contours only roughly approximate
Miles
Kilometers
Canyon
Creek
Falls Creek
O'Malley Lake
O'Malley
River
Barbara Point
Long Point
Cascade
Trail
Stony
Point

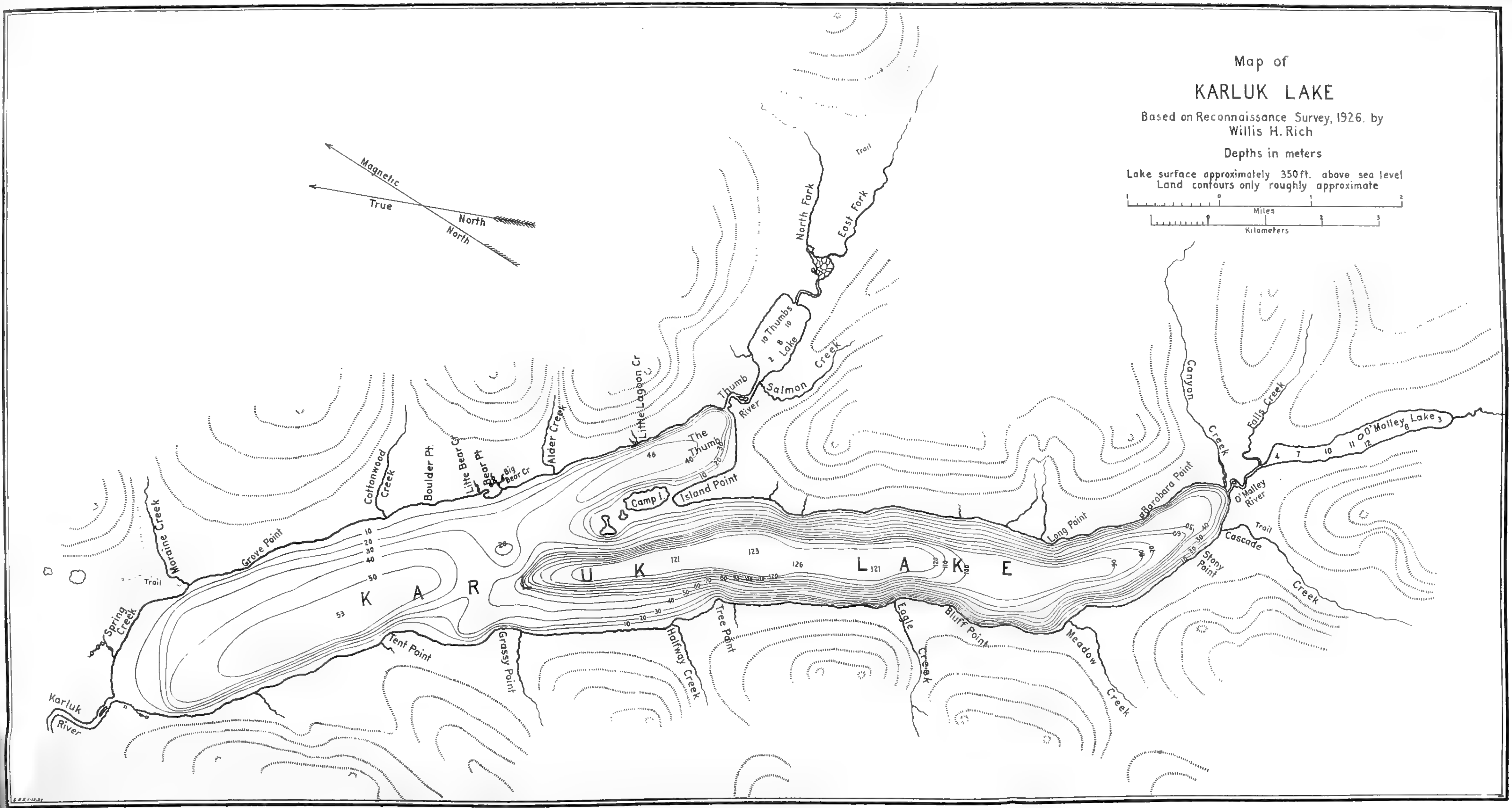


Fig. 1.—Map of Karluk Lake, Alaska

and in consequence the shore bench is very narrow and the bottom slopes steeply away from the shores. In general, the narrow beaches are composed of gravel and bowlders of varying size. Along the head of the lake, the head of the Thumb, the foot of the lake, and at a few other scattered places, the beaches slope somewhat more gradually than elsewhere and the gravel is of a size that makes these beaches suitable for spawning. In reality the lake consists of three distinct basins—one including the lower 3 miles, another including the Thumb, and the third and largest basin including the main upper arm. It seems probable that the main arm and the Thumb were formed by two glaciers which met and united just below where the islands now are situated. Apparently a small terminal moraine, which does not now rise to the present surface of the lake, forms the slight elevation that separates the lower basin from the two upper ones. The greatest depths of the lake are found in the lower part of the main arm, immediately above its junction with the Thumb, where a narrow, deep trough, 2 miles long, slightly exceeds a depth of 120 meters.

From the lower end of the lake, Karluk River flows tortuously in a westerly direction for about 2 miles; then in a northerly direction, along the western side of the valley, for some 8 miles more. At this point it is within some 3 miles of the upper end of Larsen Bay, an arm of Uyak Bay, and here there is a portage trail connecting Larsen Bay with the river. It was at this point that the upper weir was built and maintained during the season of 1926, as mentioned hereafter in the section dealing with the enumeration of the spawning escapement. Thus far the river has followed the northward extension of the valley in which the lake is situated, but it now turns westward and cuts through the mountains of the western side of the valley, and thence flows through generally mountainous country to the coast.

The descent of the river during the first 10 miles below the lake is approximately 50 feet, and most of this drop occurs in the first 4 or 5 miles. Here the river is swift and shallow, but in the next 4 or 5 miles, just above the portage trail to Larsen Bay, the river is deeper, wider, and flows much more slowly. During the late summer and fall this comparatively quiet portion is so filled with a dense growth of aquatic plants, chiefly the water crowfoot, *Ranunculus aquaticus,* and two species of Potamogeton, that it is almost impossible to navigate either with motor or oars. Below the portage the descent of the river is more rapid, falling about 300 feet in the 15 or 20 miles between the portage and the mouth of the river. About 4 miles above the mouth, the river widens out into a broad lagoon or estuary, which is shut off from the ocean by a narrow spit only 100 yards or so in width. The mouth of the river is at the western end of this spit. On the ebb tide a strong current flows out through the mouth, but on the flood tide an almost equally strong flow of ocean water takes place into the lagoon. The lower end of the lagoon, therefore, is at times very brackish, but brackish water is seldom if ever noted near the upper end. The spit that separates the lagoon from the ocean is important, since a large part of the commercial fishery for salmon at Karluk is carried on along its outer beach.

There are no large tributaries to the river below the lake. A few small streams enter, mostly from the eastern side, and these are used as spawning streams by the silver and king salmon. There are, in addition, numerous very small streams, which enter the river all along its course and drain the tundra flats and the smaller valleys of the hills and mountains through which the river flows.

The aquatic vegetation of Karluk Lake is peculiar, in that the abrupt slope of the bottom away from the shores provides little opportunity for the growth of the larger aquatic plants. The small bay near Bear Point supports a dense growth of Potamogetons, and there is a scattering growth near the foot of the lake, off the mouth of Moraine Creek, and in the shallow channel between Camp Island and Island Point. The rocks and bowlders alongshore, and to a considerable depth, are covered with a dense growth of filamentous algae of several species, however. The smaller lakes (Thumb and O'Malley) are much shallower, and in spite of their small area each of them supports a much greater growth of the larger aquatic plants, Potamogeton and Elodea, than does Karluk Lake proper. The shores of the lakes, the valleys, flats, and the lower slopes of the surrounding hills are well covered with groves of cottonwoods, alders, birches, and willows, and a variety of shrubs. By midsummer the narrow flats along the lakes and in the valleys and the more gentle slopes of the mountains are covered thickly with fireweed (*Epilobium angustifolium*) and tall grass, which make travel exceedingly difficult.

The climate of Kodiak Island is temperate. For 10 years the average temperature for the month of July (the warmest month) was 55.22° F., and for January (the coldest month) 28.92° F.[2] Karluk Lake usually freezes over in winter. According to information secured from reliable natives, who frequent the lake during the winter for hunting and trapping, it is usually frozen in by Christmas and opens again some time in April. Occasionally, however, during a very mild winter, such as was experienced in 1925–26, the lake does not freeze, but this is reported to happen only about once in 20 or 25 years. The surface temperature of the lake in summer is between 13° and 15.5° C. (55° to 60° F.). During the warm summer of 1926 the temperature for several weeks in July and August was close to 15° C., and Chamberlain reports that early in September, 1903, the surface temperature was 44° F. (6.7° C.), but that it had "fallen about 10 degrees in as many days." This would make the temperature at about August 23 of that year 54° F. (12.2° C.), and no doubt it had been higher earlier in the season.

STATISTICAL HISTORY OF THE FISHERY

Table 1 gives the yearly catch of red salmon at Karluk from the beginning of the commercial fishery in 1882 up to and including the season of 1926. The data are presented graphically in Figure 6.

The catch of 1882 contained less than 60,000 red salmon, but this increased rapidly until by 1888 the annual catch was greater than 2,000,000 fish. A high level of productivity was maintained, with only occasional poor catches, for about 20 years. During this period, from 1888 to 1907, the catch fell below 1,000,000 fish only once, and the average yearly yield was 2,304,803 fish. Since 1907, however, the catch has been appreciably less. In this period of 19 years there have been seven in which the catch fell below 1,000,000 fish, and the average yield for the entire period was only 1,306,152. It is apparent from the graph, furthermore, that it is not only the average yield that is reduced in the later years, but that both the maximum and the minimum yields are getting smaller. In other words, the good years have been getting poor and

[2] Geological and Mineral Resources of Kenai Peninsula, Alaska. By G. C. Martin, B. L. Johnson, and U. S. Grant. Bulletin, vol. 587, United States Geological Survey, 1915. Washington.

FIG. 2.—Seining beach at Karluk Spit, Karluk Head in background

FIG. 3.—Mouth of Karluk River

FIG. 4.—The counting weir situated just above the estuary

FIG. 5.—Salmon passing through one of the gates oi the tounting weir. Note the white-painted canvas fastened to the bottom, which improves the visibility, and the wire leads, which require the salmon to pass over the canvas

the poor years have been getting poorer. There is clear evidence here of depletion, although, fortunately, it has not become as serious as in some other localities. With the present requirement of a minimum escapement of 1,000,000 fish, which has been in force since 1925, it is hoped that the level of productivity may once again be raised, but it will not be until the season of 1930 that the catch will be affected by this regulation.

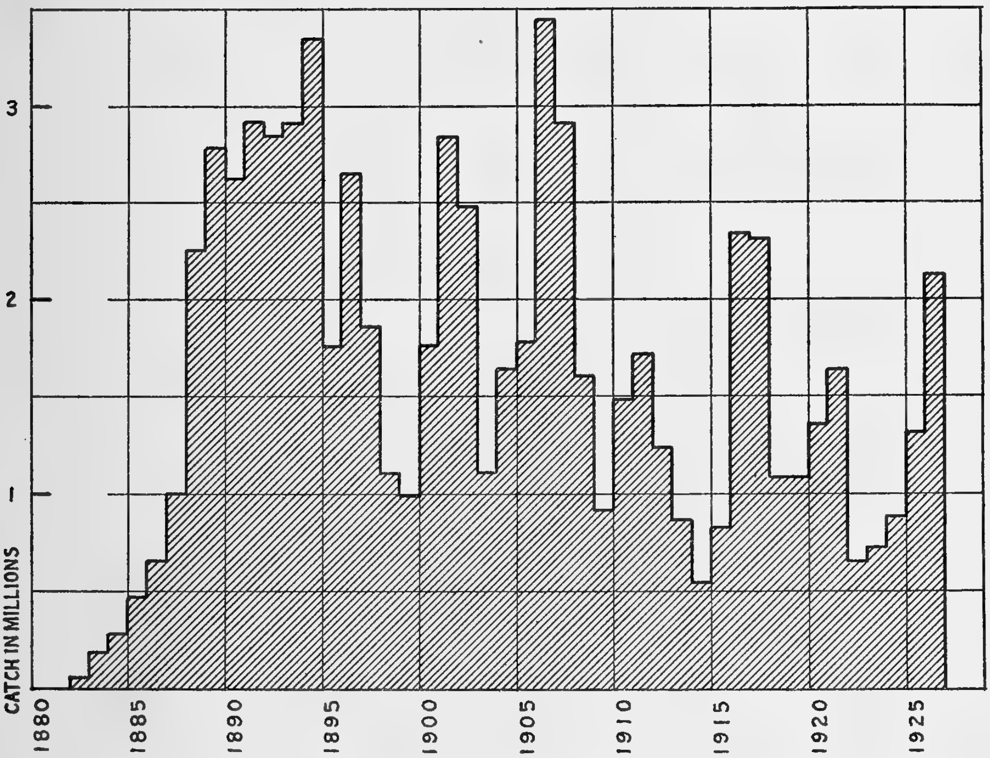


FIG. 6.—Yearly catch of red salmon at Karluk since the beginning of the fishery in 1882 to 1926

TABLE 1.—*Catch of red salmon at Karluk and immediate vicinity from beginning of canning industry in 1882*

[For the period from 1882 to 1894, inclusive, the figures herewith are based on an estimate of 14 red salmon per case]

Year	Number of canneries	Number of fish	Year	Number of canneries	Number of fish	Year	Number of canneries	Number of fish	Year	Number of canneries	Number of fish
1882	1	58,000	1894	4	3,349,976	1906	2	3,453,113	1918	3	1,092,775
1883	1	188,706	1895	4	1,762,000	1907	2	2,929,886	1919	2	1,089,809
1884	1	282,184	1896	3	2,650,000	1908	2	1,608,418	1920	2	1,368,526
1885	1	468,580	1897	3	1,865,731	1909	2	923,501	1921	4	1,641,758
1886	1	646,100	1898	3	1,102,957	1910	2	1,492,544	1922	5	658,159
1887	1	1,004,500	1899	3	991,848	1911	2	1,723,132	1923	3	727,730
1888	3	2,256,100	1900	2	1,767,671	1912	2	1,245,275	1924	4	890,752
1889	5	2,792,930	1901	2	2,841,247	1913	2	868,422	1925	4	1,317,993
1890	5	2,622,396	1902	2	2,485,112	1914	2	540,455	1926	4	2,131,616
1891	5	2,926,588	1903	2	1,109,975	1915	2	828,429			
1892	3	2,852,458	1904	2	1,638,949	1916	[1] 2	2,343,104	Total		73,561,823
1893	5	2,909,508	1905	2	1,787,618	1917	2	2,324,492			

[1] Part of these fish were transferred to canneries of the Alaska Packers Association at Alitak, Chignik, and Kasilof.

Figure 7 shows graphically the annual catches from 1896 to 1926, both inclusive, broken up into five-year cycles, of which there are six complete cycles and a seventh just beginning with 1926. No attempt was made to include the data for the years previous to 1896, as these data obviously are not comparable with those since that date. During the first few years (from 1882 to 1888) the industry was growing rapidly, and during the years from 1888 to 1895 it profited from the intensive exploitation of a practically virgin field. Since then the annual runs have presented a more or less regular sequence of events.

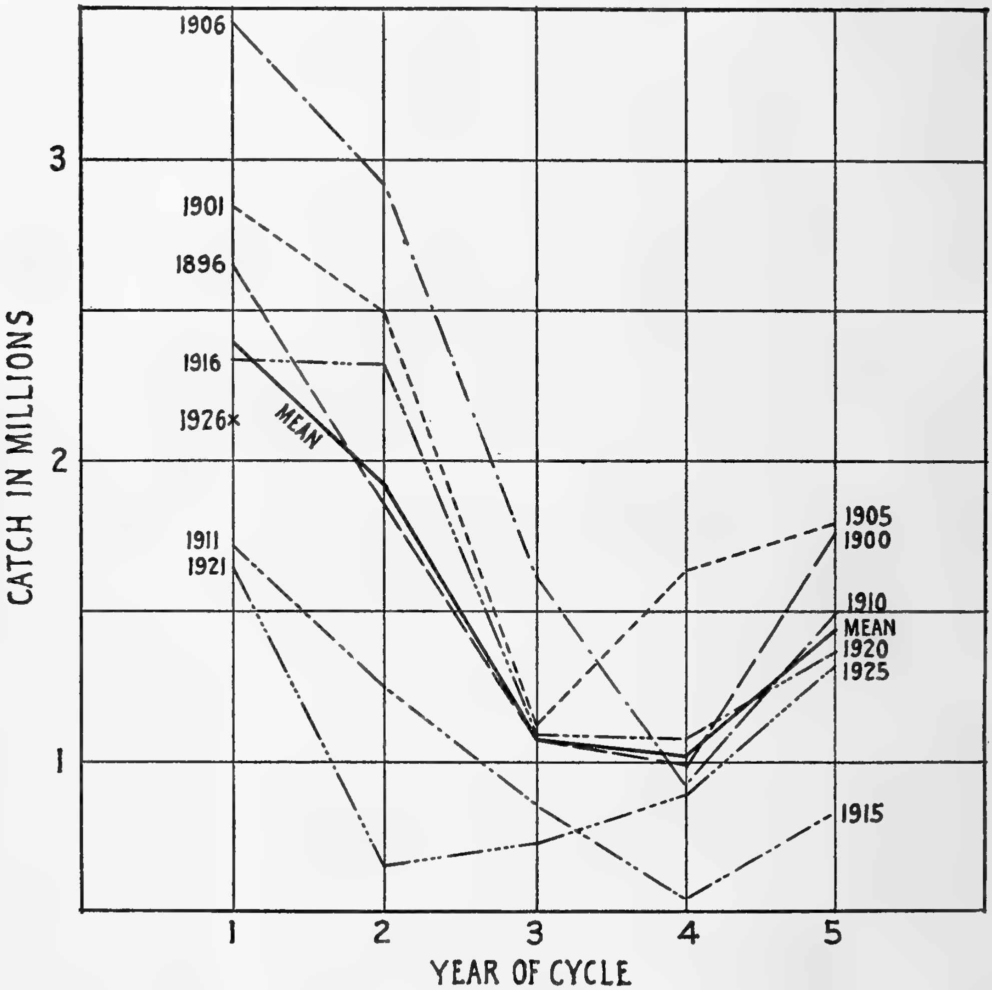


Fig. 7.—Catch of red salmon at Karluk in 5-year cycles, from 1896 to 1926

The graph shows clearly the cyclic character of the runs of red salmon in the Karluk River. Since the Karluk salmon are predominantly five-year fish, we anticipate a correlation between the run of any year and that of the fifth year preceding, the fifth year following, etc. With the exception of one of the six cycles, it is apparent from the graph that the Karluk runs consist of two good years followed

by three poor years—the good years are those ending in the figures 1, 2, 6, and 7, and the poor years end in the figures 3, 4, 5, 8, 9, and 0. This is well shown by the line of the mean, which is also shown on the graph.

The last cycle, that involving the years 1921–1925, differs from the others in that the second year is conspicuously the poorest one of the series. The other four years of the cycle, however, do conform very well with the corresponding years of the other recent cycles. Something obviously happened to reduce the yield of 1922 below that of the corresponding years of previous cycles.

No one can examine such a series of data without being impressed by the conspicuous correlation between the size of the catch in the corresponding years of the several cycles. There is a remarkably uniform tendency in each cycle, as shown on the graph, for the catch of the second year to be smaller than that of the first, for that of the third to be smaller than that of the second, for the catch of the fourth year to be about the same as that of the third, and for that of the fifth year to be greater than that of the fourth. If it can safely be assumed that spawning escapements are in the main roughly proportional to the catch, it becomes apparent that they are the predominating factor in determining the size of the runs.

That other factors may intervene is shown by the sudden drop in the catch from 1917 to 1922. The catch in 1917 was 2,324,492, while that in 1922 was only 658,159—one of the poorest on record since the fishery became well established. This is discussed in detail hereafter in the section entitled "Analyses of recent runs."

OBSERVATIONS ON THE SPAWNING GROUNDS

For its size, the Karluk River probably supports the most magnificent run of red salmon of any known stream—at least, of any stream on the American side of the north Pacific—and it has maintained this run in fair measure in spite of the very intensive fishery which has been conducted at the mouth of the river for more than 40 years. From time to time representatives of the Bureau of Fisheries have visited the lake and recorded something of the conditions found there during the spawning season. The earlier observations were only occasional and largely of the nature of general surveys. Eight years ago, however, the senior author of this paper undertook a more detailed and intensive study of the Karluk red salmon, and, as a part of this, regular yearly surveys of the spawning grounds have been made. At first these were intended to supply some measure of the extent of the spawning escapement, but a much more accurate measure of the escapement (by means of weirs, through which the fish are counted) was later adopted and has been in use since 1921. The observations on the spawning grounds are of great value, however, in showing the conditions under which the spawning takes place, and will help materially to determine the relative success that may be anticipated from the successive spawnings.

There are only two published accounts of observations of the spawning in Karluk Lake—those of Bean [3] and Chamberlain.[4]

[3] Report on the salmon and salmon rivers of Alaska, with notes on the conditions, methods, and needs of the salmon fisheries. By Tarleton H. Bean. Bulletin, United States Fish Commission, Vol. IX, 1889 (1891), pp. 165–208, Pls. XLV–LII. Washington.

[4] Some observations on salmon and trout in Alaska. By F. M. Chamberlain. Report, United States Commissioner of Fisheries for 1906 (1908). Bureau of Fisheries Document No. 627, 112 pp., illus. Washington.

Bean, with a small party, spent about four days at the lake—from August 17 to 21, 1889. A fairly good map of the lake was made and is published in the report, which contains an interesting and accurate description of the lake and river and of the fishery as then conducted at the mouth of the river. Regarding the spawning, Bean says:

Karluk Lake receives the waters of numerous small streams, in which salmon and trout are found whenever they are not prevented from entering them by an abruptness of the ascent. Each of the arms of Karluk Lake is connected by a short, rapid, and crooked river with smaller tributary lakes. The lake tributary to the east arm is about four-fifths of a mile in length, and the one connecting with the west arm is about 1½ miles long. In the small tributaries of Karluk Lake the rivers connecting its arms with their principal lakes and at various places around the shores of the principal lake—particularly at its southern end, between the mouths of rivers—we found nests of the red salmon. * * * The small rivers connecting Karluk Lake with its tributary lakes contain no obstructions to the passage of the salmon. These lakes freeze over in winter, and the natives travel over them to attend to their traps. They claim that they can obtain salmon at any time during the winter through the ice.

On the basis of observation made by Cloudsley Rutter during the summer of 1903, Chamberlain gives only a meager description of the lake and its tributaries and of the extent to which the various tributaries were used by the spawning fish. The following quotations from his report contain most of his remarks on the spawning of 1903:

There are numerous small streams entering the main lake, some of which, as the outlets of the tributary lakes, are of considerable length and suitable for spawning ground, while others are swift mountain torrents with rough beds, which offer but small areas for the fish. The shores of the lakes also are utilized for spawning.

The early arrivals of salmon spend some time in the region of the spawning beds before depositing any spawn. In the Naha the first sockeyes reach the lakes in June, but none spawn earlier than about the middle of August—after a lake residence of about six weeks. In the Karluk, in 1903, the first sockeyes entered the lake about the middle of June; they continued to arrive in numbers until the latter part of July. They spawned during August. The first arrivals, as in the Naha, thus spent about six weeks in the lake, and all remained at least four weeks before spawning. In the Fraser basin, in 1905, the first fish reached Seton Lake the latter part of July, the run continuing until the latter part of September. The first eggs were spawned the first week of September, and spawning continued until late in October. This was approximately the same length of residence before spawning as in the Naha and the Karluk.

During the residence in the lakes it is improbable that the fish occupy the greater depths, since it has been shown that these are not suitable for fish life. In the evenings salmon may often be seen in numbers "finning"—i. e., swimming leisurely at the surface in such manner as to expose the dorsal fin. The sockeye seldom jumps in lakes until about to approach the spawning bed, when there may be a slight demonstration of that habit. Ordinarily a lake may be filled with adult fish and no evidence of their presence noted by an observer.

Karluk Lake has many tributary creeks that are used by spawning fish, but the total area seems scarcely commensurate with the enormous productiveness.

In 1903 a careful count was kept of the sockeyes spawning in one stream of Karluk Lake, the second from the outlet on the right or east side.[5] This is a small creek, averaging some 10 feet in width, about 1 mile of which is used for spawning beds. From August 5 to September 5 of that year 21,756 spawned fish were examined in this creek, presumably the total number spawning there in that time, and practically the total for the season. Of these, males were in excess by about 3 per cent, the number being 10,723 females and 11,033 males. But one unspawned female was found dead. Dead unspawned males are more common. Of 636 females opened, about 80 per cent

[5] This is, without much doubt, the creek to which we have given the name "Moraine Creek."

were entirely spawned out; i. e., with no loose eggs in the abdominal cavity; the remaining 20 per cent had an average of 97 eggs unspawned, with the most in any instance noted 1,246. The sockeye carries between 2,500 and 4,000 eggs, an average, perhaps, of about 3,500. This remnant, then, amounts to about one-half of 1 per cent of the total number of eggs matured. The product of this one stream, on the same basis of estimate, is 37,000,000 eggs. It is believed that less than one-tenth of the number of fish entering the lake spawned in the above-mentioned creek. Thus, approximately 400,000,000 sockeye eggs were spawned in Karluk Lake basin in 1903. Sockeyes are reported by natives to spawn late in the winter, even under the ice, but it is doubtful whether it is usual for any noteworthy number to occur as a fall run, as with other species and in more southerly streams.

In 1903 the spawning season was practically over early in September. Since the fishing continues ordinarily into that month, the spawning should last much later. The double operation of cannery and hatchery, perhaps, accounts for its early close.

On Karluk Lake in 1903, in the creek on which the spawners were counted, these beds were examined by digging in the gravel to find the condition of the deposited eggs. Between August 5 and September 2, 58 "nests" were examined. In these were found 4,005 good eggs and 2,022 dead ones, or, in other words, about two-thirds of the buried eggs were found to be in good condition. On the latter date 587 eyed eggs were found under about 10 inches of gravel, with only 13 dead ones. This demonstrates that eggs will live and develop under proper conditions when deeply buried. In another stream, in the center of a nest, under 6 inches of gravel, only 29 of 620 eggs recovered were living. In a third bed, of 1,140 eggs taken from the lower half of the nest, in a light current and from under 7 inches of gravel, only 28 were dead. In general, the observer records few eggs from locations in strong current; this was possibly in part from failure to find the eggs as well as from their scarcity. Most beds show a decided balance in favor of the good eggs. In two examinations of the connecting stream from one of the tributary lakes less than 4 per cent of the eggs were dead.

Our observations, particularly those made in 1926, do not support the idea advanced by Chamberlain that the early arrivals that reach the lake about the middle of June remain in the lake until August before spawning. In 1926 the very heavy early run was spawning abundantly by the 10th of July, and apparently had completed spawning entirely before the 1st of August. In 1926 Moraine Creek was well seeded by this early run and was also used extensively by the later runs—those that spawned in the early part of August, at the same time Rutter's observations were made. Unless conditions were very different in the two years, then, it is difficult to believe that the 21,756 spawning fish counted in 1903 represent the total for that season, although no doubt it is a close approximation to the number in the creek during August. It is quite probable that conditions were vastly different in 1903 than in 1926, and that the early escapement was very much smaller. Certainly, if Moraine Creek in 1903 had received anything like the early spawning run it had in 1926 the remains of dead fish would have attracted the attention of a well-trained observer such as Mr. Rutter.

In 1911 a brief visit was made to Karluk Lake by Ward T. Bower and party. Unfortunately, it has been impossible to find the detailed notes made at the time, so that the only available information is contained in the following quotations from a section of an administrative report: [6]

An exploration was made of Karluk Lake the latter part of July primarily for the purpose of locating a hatchery site. A tributary stream near the lower end of the lake appears to be suitable

[6] Fish Culture in Alaska. By Ward T. Bower. *In* Alaska Fisheries and Fur Industries in 1911, by Barton Warren Evermann. Report, United States Commissioner of Fisheries, 1911 (1913). Bureau of Fisheries Document No. 766, pp. 66–88. Washington.

for this purpose. The lake is about 8 miles long and averages 1 mile in width, but the quite precipitous mountains which almost surround it leave remarkably few tributary streams accessible to the salmon for spawning purposes. The result is that many salmon spawn in the lake along the gravelly beaches. On August 1 the lake contained a large number. Two small lakes drain into Karluk Lake, the outlet of which is Karluk River, a stream shown by compass survey some years ago to be approximately 15 miles long. * * *

Of 200 [dead] females selected at random September 12 at Karluk Lake, it was found that 197 had spawned clean, 1 contained about 1,000 eggs, while the other 2 had about 150 eggs, which had died with the fish.

The stream mentioned as being suitable for hatchery purposes is presumably the same one in which Rutter's observations were made and which we have called Moraine Creek. Bower's observations during a very short visit to the lake, and his notes on the extent of available spawning streams, are in error, as our later and more extensive observations show. His notes on the completeness of spawning are important, however, as they check with those of Chamberlain, and both are at variance with the observations made by us during the very heavy spawning of 1926.

The next examination of Karluk Lake was made in the fall of 1917 by E. M. Ball. The following extracts from his report deal with the spawning of that year:

September 12.—This part of the river (the upper two miles) formed the spawning ground of a large number of red salmon, the river bottom being a mass of spawning beds. No trout were observed in this part of the river. Camp was made at the lower end of the lake.

September 13.—Left camp at 6 a. m. and proceeded along the southern [western] shore of the lake, making an examination of all streams as they were passed. Six streams of fair size enter the lake from the south [west]. All of them were occupied by spawning salmon, and around the mouth of each was a bank of dead fish that had spawned and drifted down the stream to the quiet waters of the lake. Piles of salmon had also accumulated at several points along the stream where brush and rocks had caused them to lodge. The shore of the lake was the resting place of thousands of skeletons of salmon. At the head of the lake are two much larger streams, one of which is the outlet of another lake, whose length is approximately 3 miles. The connecting stream is probably half a mile long and has an average width of 70 feet. The valley between the two lakes is simply a network of streams, all of which have gravel bottoms affording perfect grounds for the deposit of spawn. Thousands of salmon were then spawning, and yet other thousands had spawned and died. Trout were rather abundant also. Several streams enter the lake from the north [east]. Each of them seemed to have its share of salmon. We had intended to camp for the night on an island about the center of the lake, but threatening weather conditions caused us to return to the camp at the end of the lake, which we reached about 9 p. m. From sundown, until darkness prevented further observation, the lake was alive with feeding fingerlings.

It would be a difficult matter to estimate the number of salmon that had reached the lake. The run was still on, and those in the lake had not all approached the streams. A fair estimate of the number that had spawned, as indicated by the quantity of skeletons and dead fish observed in the streams and lake, together with those then spawning, would exceed 200,000 salmon.

In the late summer of 1919 Henry O'Malley, the present Commissioner of Fisheries, and the senior author made a very brief examination of the spawning in Karluk Lake. Unavoidable circumstances prevented the complete survey that had been planned. Observations were made on Cottonwood, Moraine, and Spring Creeks and along the foot of the lake. The same party again visited the lake in August, 1921, and their observations are recorded in the following notes taken from the diary of the senior author. Since these notes contain references to the observations of 1919, it has not seemed desirable to quote separately the notes made during the first brief visit.

August 8.—On upper 2 miles of river saw very many king salmon, often milling around in pairs. At foot of lake saw *no* large school of red salmon, such as was strikingly in evidence two years ago.

August 9.—Red salmon jumping all night outside Tent Point. Several dead males had drifted up on the shore, and a few were constantly swimming up and down along the beach. A creek enters at head of the bay on the northwest side of the point,[7] and many gulls were congregated at its mouth. The point has coarse, gravelly shores and bottom. The gravel is displaced in spots, but no definite nests have been observed.

The morning is fine; sky hazy; a few fog wreaths across face of mountains. No wind. Air 57°, water 54°, at 8 a. m. Creek near point 48°.

Visited creek above camp. About 2 or 3 feet wide and a mere trickle of water. Several hundred salmon densely crowded off mouth. Occasionally one or two scuttled up the beach through the trickle, the entire head and body exposed. The creek meanders through the low ground; bottom small bowlders and cobbles; no good spawning beds. Last evening a flock of gulls camped continuously on beach at mouth of creek, as though interested in eggs floating down.

Photos taken of fish off mouth and of fish partly eaten by bears a short distance upstream, where grass was trampled and evidence unmistakable of their presence last night or yesterday. Spawning had been in progress *along beach* and off mouth of creek.

Fitted Evinrude to boat and left for head of lake 9 a. m. Went directly out from Tent Point to middle of lake and sounded with a depth of 181 feet. [Approximately 54 meters, agreeing with our later measurements.][8]

After sounding, started up at 9.30, following west shore to examine creeks. About half way on west side is a creek (Grassy Point Creek) about 6 feet wide and now 6 inches deep, thickly beset with dead and living fish. Temperature 46°. In the lowest 1,000 feet (paced) we counted 1,400 dead salmon, and estimated that side branches contained as many more (4,800 in all), and that there are fully as many live salmon as dead ones. It is safe to say, counting those now preparing to enter the mouth, that there are 10,000 fish spawning in the lower 1,000 feet of the stream. Apparently about 1 mile of stream with spawning in progress, and probably 50,000 fish in all.

Gulls were thick at mouth of creek and some were encountered higher up. They were feeding on drifting eggs, which could be seen in every eddy. Creek bottom of coarse cobbles and gravel, very hard, apparently not dug up. Seems impossible eggs could be buried, and loss must be enormous.

Halfway Creek is larger than Grassy Point Creek, 15 to 20 feet wide in places, steeper, with swifter current, temperature 46°. Contains not half as many salmon, dead or alive. Bowlders larger. Floating eggs numerous; a flock of gulls at mouth. Went upstream to falls, perhaps one-fourth mile from mouth. These are impassable—may be 2,000 or 3,000 fish below them. Fewer dead fish, proportionately, than in Grassy Point Creek.

Sounded in middle of lake, opposite Tree Point, obtaining depth of *405 feet* [121 meters, agreeing exactly with later measurements].

At 2.40 p. m. reached a stream entering from southwest [Meadow Creek], at projecting point in south arm near head. Stream 10 to 15 feet wide, full of live and dead fish, containing probably more salmon than any other stream seen to-day. Gentle ascent, temperature 47°. The creek was explored for over half a mile and found fish thick all the way. Found no falls.

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7 This is a small creek, shown on the map, but has been given no name. It may be called Tent Point Creek.

8 The method by which these soundings were made is thought worthy of record. A number of spools of stout linen thread were provided, each marked as containing 100 yards. This measurement, on test, was found to be quite accurate. A number of small lead weights, weighing about one-half pound each, also were on hand. When a sounding was to be made, a weight was tied to the thread of one of the spools and let down to the bottom, while the boat was kept in position so that the thread led down vertically. The unreeling of the thread was made easy by inserting a heavy wire nail through the spool and allowing the spool to turn freely on the nail. When the weight had reached bottom the thread was broken off at the water line, the spool marked so that it could be later identified, and the thread left on the spool measured. The difference between this amount and 100 yards gave the depth at the point where the sounding was made. In cases where the depth was greater than 100 yards a second spool was used and the thread tied to the end of the thread of the first spool. The amount left on the second spool subtracted from 200 yards gave the required depth. The results obtained by this method have checked so consistently with those secured in 1926 through the use of a regulation fathom wheel that it is safe to say that the accuracy of the method here described compares very favorably with the customary methods of sounding.

August 10.—Air 56°, lake 53°. Tree Point projects far into lake—low, with row of cottonwoods. Is beyond entrance to Thumb Bay. Looking north from Tree Point, farthest point is Tent Point, Halfway Point being indistinguishable, as it does notproject far and is evenly rounded. South from Tree Point one or more gently rounded projections, not worthy of name, then a conspicuous point completely hiding the shore beyond. This point is fairly bold, the crest of the descending ridge with dense growth cottonwoods. This we call *Eagle Point,* and there is no stream of importance between it and Tree Point.

On reaching Eagle Point found it to be a broad projection, one-eighth mile across, with wavy outline, and a southern low sandy point not worth designating. Beyond that the shore recedes in a convex curve to a rather deep bay, across which the triangular green slope of MeadowPoint is seen, bounding the south side of the bay and with a row of trees beyond (i. e., across) the green. A fairly definite, steep, green point bounds the north end of the deep bay (Bluff Point), from which, looking north, only Eagle Point can be seen. One hundred yards outside Bluff Point, Eagle Point and Tree Point are in line. From Meadow Point north Eagle Point projects beyond the rest of the shore line.

A mile above Meadow Point fish are spawning along shores, with dead fish at bottom, showing this has been going on all season, but total number is inconsiderable. This spawning beach runs along a steep mountain side. A small creek, about 3 feet wide, enters middle of beach, and seepages undoubtedly exist. Arrive creek 11.45 a. m., about 1⅓ miles above Meadow Point Creek. About 500 live fish in lake at mouth. No fish to speak of upstream, although accessible and better bottom than usual. No dead fish in stream. Apparently late run. Eggs in better shape. Temperature 49°.

Off at 12 m. Around first point above creek, several hundred fish spawning along beach. In bay above, perhaps 200.

Cascade Creek. Next creek 12.10, one of three at head of south arm. Largest creek yet seen, 10 feet wide, with finer gravels. Fish spawned early, many dead and living. Temperature 50°. Contains about 1½ miles of spawning stretch and is better adopted to spawning than any other stream thus far seen. Materials finer and current less boisterous. Eddies contain many eggs, not one in five alive. Compared with other creeks visited, there are fewer dead salmon. Looks as though run might be relatively late.

Off at 1.25 p. m. Salmon spawning heavily in fine materials of beach for 200 yards above Cascade Creek and at intervals all the way to O'Malley River. Temperature upper lake 59°.

O'Malley River is about half a mile long, meandering in an almost level broad valley. Has fine gravels, excellent for spawning; yet, compared with other streams below, it has few fish. The upper lake, seen at first only from the lower end, was apparently 2 miles long.

A stream [Falls Creek] enters O'Malley River shortly below the lake, with temperature 54°. It carries about as much water as comes out of the lake. Fish running up this stream from O'Malley River, but comparatively few. In 200 yards of this stream counted 677 recognizable dead salmon. Where this stream joins O'Malley River a tally for a brief period showed an average of 3 passing up O'Malley River into the upper lake and 16 passing into the colder stream, Falls Creek.

Came back down old channel, with many times more dead and living fish. Temperature 55°.

Dragged boat up the river to O'Malley Lake, and started to head of lake. Stopped at a small creek coming in on west side, half way up lake; temperature 48°. About 200 fish spawning in fine gravel off mouth, but apparently none entering, although stream more favorable in appearance than many we have seen occupied. Many soundings were taken in O'Malley Lake below the island, where greatest depth was 35 feet, about 10 meters, and this was several times repeated. Above island, in middle of lake, depth was 10 feet.

The inlet at the head of the lake is a small sluggish creek, perhaps 12 feet wide and 6 to 12 inches deep, meandering through a nearly level bottom. It is only a short distance to impassable falls. Saw very few fish, no dead ones, except along the banks, fragments partly devoured by bears. Temperature 50°. Probably not more than 100 or 200 salmon in this stream. The whole lake seems useless as spawning ground.

Returned to shore of Karluk Lake at 5.35 p. m. Temperature of O'Malley River near mouth 54°. Another stream (Canyon Creek) enters Karluk Lake within 100 yards of O'Malley River. Same character—wide, gently flowing over fine gravels—an ideal spawning stream. Temperature

FIG. 8.—The Thumb, Karluk Lake, from Camp Island

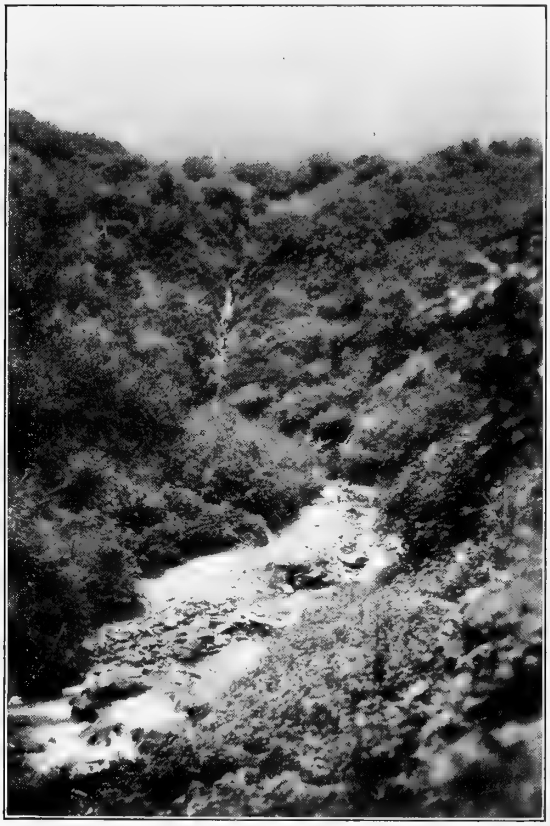

FIG. 9.—Salmon Creek, near the falls

Fig. 10.—Salmon Creek, near its mouth, at the height of the spawning in July, 1926

Fig. 11.—Thumb Lake, from its lower end

50°. Lower course with many dead and far more numerous living fish, which are in fine shape. This is equally important with O'Malley River. Length unknown to us. It is reported to be only a mile to impassable falls.

Walked around head of bay and down north shore to Barabara Point. The head of bay, beyond Canyon Creek, fronting low land, was one mass of spawning fish for 20 or 30 feet off shore. Camped at Barabara Point.

August 11.—Water of lake colder, 50° at 7.50 a. m.

Below Barabara Point, perhaps 300 yards, a small creek with perhaps 100 salmon around mouth. Earlier a few ran up and perished. Stream now 2 feet wide.

Took a sounding in middle of lake near entrance to South Arm, depth 235 feet (70 meters). Another off Long Point (east shore), depth 305 feet (91 meters).

Running down middle of lake to sound against stiff breeze. Opposite Bluff Point at 10.25 Reached sounding station opposite Eagle Point, in middle of lake, 10.35. Depth 405 feet (121 meters); same depth as off Tree Point.

Reached head Thumb Bay at 12.20. Temperature of bay 56°; of Thumb Lake 54°; of Thumb River 52°. Found dead on bank of Thumb River a red salmon 8 inches long, testes mature, had black spots on back but none on tail. Examined gill rakers, found to be characteristic.

Thumb Lake is shallow throughout, strewn with glacial bowlders near lower end. Soundings 20 and 33 feet (about 10 meters). Thumb River at mouth very wide and shallow, with two openings. Salmon constantly entering and floundering up the shallows, with backs exposed. They are numerous, but not crowded, all the way up to Thumb Lake, where most of them pass into a small stream, which enters from the left bank (looking downstream), immediately at foot of lake (Salmon Creek). A constant procession enters this tributary, said to be about 1 mile long. After witnessing intensity of spawning in Grassy Point and Meadow Creeks am impressed by fact that the apparently more favorable creeks are not crowded.

Upper Thumb River is full of "dollies." One examined (15 inches) had not been feeding and had testes white, though no liquid milt was present. Watching the "dollies" in creek, a number were seen turning on sides and rubbing against bottom as though spawning, but could not be sure that spawning was in progress. Contains few salmon, dead or alive. Said to be 1½ miles to impassable falls.

Leaving Thumb Bay for the foot of the lake we passed two or three very small creeks, all with a few salmon off mouth and entering. At 5 p. m., having made about 4 miles, we reached Cottonwood Point and camped at mouth of Cottonwood Creek, 10 to 15 feet wide, descending by gentle grade. Bowlders of large size are present, but finer materials make spawning possible, with covered eggs. Perhaps a hundred fish were thickly clustered off mouth, and were entering at intervals through water so shallow that the whole back and head were bare. Above, the stream is *thickly crowded* with spawning fish, which are almost as numerous as in Meadow Creek, in proportion to size of stream, and far more numerous than in O'Malley River. Temperature 53° at 5.30 p. m.

August 12.—Temperature, Cottonwood Creek, 49°, lake 50°, at 7.45 a. m. Salmon entering freely.

Reached Moraine Creek, at 9.45 a. m. Temperature 49°. This is one of the principal spawning streams, to be compared with Cottonwood Creek. Perhaps averages 15 to 20 feet wide, 6 to 8 inches deep, rapid current, but suited for spawning, except for too coarse materials. This creek was examined by O'Malley and me in 1919; apparently fewer fish this year. O'Malley thinks one-third less. The stream is well stocked, however, and may well be called crowded. Hundreds of fish are spawning along the beaches, for 100 yards or more north of the mouth. Rough estimate 20,000 salmon, many more alive than dead. Rutter visited this creek in 1903, walked down from falls (1½ miles) to mouth, and estimated 30,000 dead and alive.

Water 200 feet to north of mouth of Moraine Creek was 49½°, that of creek 49°; general surface temperature of lake, away from any stream, at 10 a. m. 50°.

Spring Creek at 10.20. Temperature 44°. First pond 49°, fed by stream 47°. Upper pond 46½°. More than twice as many fish this year as in 1919, but none too many. Upper pond perhaps 150 feet long by 60 feet wide. Fish spawn all through the small creeks which connect the ponds, and in the ponds, the creeks often not more than 2 feet wide. Counted 200 dead in upper pond. A third pond, still larger, was full of dead and living fish. Is fed by springs and has no inlet. About

250 feet long by 100 feet wide, depth 1 foot. Temperature 45½°. It has a little offset at bay at upper end, not included in estimate of size. Following measurements taken of dead fish in pond:

Males:	Females:
25½ inches.	25 inches.
24½ inches.	22½ inches.
25 inches.	23 inches.
24 inches.	21½ inches.
26 inches.	21½ inches.
23½ inches.	22 inches.
26 inches.	21 inches.
24 inches.	23½ inches.
24 inches.	24 inches.
22 inches.	23 inches.
25 inches.	23½ inches.
21 inches.	22 inches.
24 inches.	21 inches.
23 inches.	23 inches.
	23½ inches.
	23 inches.
24. 1 inches (average).	22. 7 inches (average).

Outlet of lower pond at mouth, 49°. Where Cold Creek (a small branch of Spring Creek, not named on the map) flows past outlet of lower pond, 39½°. Saw salmon leaving main stream (temperature 40°) and entering warmer water of pond outlet, and this must have been true during most of spawning season. Cold Creek has but few fish in it and practically no dead fish. It is less than 100 yards long above junction with Pond Creek and originates in springs.

Opinion of O'Malley and myself, four or five times as many salmon in Spring Creek as in 1919. This year it is a highly valuable spawning stream. It averages deeper than other tributaries to Karluk Lake, has fine gravel beds, and is able to care for a good run, probably even more than it had this year. It is a short stream, probably half a mile long.

Left at 11.40 a. m. for foot of lake, about one-fourth to three-eighths mile distant. The great school of salmon at foot of lake in 1919, estimated as containing 10,000 fish, was not present this year. Temperature of river, 60°.

The two authors of this report visited Karluk Lake together in 1922, accompanied by W. P. Studdert and Fred Lucas. At this time the junior author made a preliminary survey of the lake and tributary streams, while the senior author was concerned primarily with observations on the spawning grounds. The following notes are taken from the diary kept by the senior author:

August 18.—The river in the shallows below the portage was alive with king salmon, milling around, splashing, finning, and spawning. A few humps were with them in the shallows, but a very large number were resting quietly among the waterweeds, closely packed, side by side, their white bellies very conspicuous. These had probably reached this stretch of the river before becoming ripe, and were awaiting that event before going out on the spawning beds. The bottom of the stream where they lay was not suitable for spawning purposes. They are marked not only by the conspicuous white belly, but by the light or orange front and upper margin of the dorsal fin (an upper anterior margin) and by the bright reddish orange gill membrane.

Looking upstream from portage, few fish were seen. The character of the stream for two or three miles (or more) is not favorable. In this quiet, weed-grown (*Ranunculus aquatilis* and others) portion of the river, with slack current, few salmon remain.

Before entirely passing the mountain on our right, along the base of which the river runs for several miles, the current becomes more swift, the depth less, and the bottom most uneven, due to the gravel heaps made by spawning salmon. Humpbacks and kings were spawning on all suitable shallows and riffles from here to the lake, the humpies much the more numerous.

August 19.—On our way up the river we had seen scattering red salmon, but never in any numbers. It was not until we reached the final shoals below the lake that red salmon became a feature. In this short section, of perhaps a quarter mile, there were more reds than humps, and also a good sprinkling of kings. The reds were not moving up into the lake, as far as we could observe, but were acting in all respects like the kings and humps spawning along the river. Many pairs were seen; they were milling around and finning and fighting, for all the world like those seen later along the lake shores. Some males were frayed. They were undoubtedly spawning.

As regards the number of humpbacks found along the river, it can be said they were abundant in all shallow gravelly stretches with good current. The gravels were not fully occupied; there was easily room for twice the number, but the impression was strong that they were numerous, perhaps sufficiently so.

Kings were not seen by us between the portage and the last stretch of river before reaching the lake, although it is reported that the deep hole 2 or 3 miles below the lake is a favorite spot for them to lie in and then spawn near at hand. We saw many king salmon in this hole two years ago. This year they were numerous immediately below the lake. They were even spawning in the foot of the lake itself, in the channel at one side of the sand island that lies where the river current begins; but not a single king was seen last year or this beyond that point. The lake shores and tributaries were free from kings.

Thumb River. The lowest stretch (perhaps one-eighth mile) of this short stream pursues a westerly course and is very wide and shallow, much like the main Karluk River immediately below Karluk Lake. Sand bars and islands at the mouth divide the current this year in three channels, the southwest channel the largest. This section of Thumb River is a favorite spawning ground and was thickly beset with spawning fish. At first sight it seemed to reproduce the conditions of last year. Spawners were everywhere in considerable numbers, and more were entering constantly; but inspection showed that here, as in the main river, humpbacks far predominated over the reds. I estimated conservatively 1 red to 5 humps; Lucas, 1 to 20.

At the upper end of this lower east-west portion of the river it turns abruptly south, and then swings back in a wide curve to the foot of the lake, which has the same axial line as Thumb Bay. The river is less than half a mile long and was beset with humps for its entire length. Where the outlet leaves Thumb Lake, a tributary of some size comes brawling in at a sharp angle, from south or southwest, and is a favorite spawning ground for red salmon. Far more spawn in this stream than in Thumb Lake or in all of its other tributaries. A bar or flat at the mouth of this tributary was deep in dead red salmon last year, whereas this year comparatively few were present. We enumerated 625 dead salmon at this point, including all that could be seen lying in deeper water immediately off the mouth. Lucas and Studdert went up this stream the following day about three-fourths mile to a fall, which blocked further progress. Studdert counted 251 live fish, and is certain he did not miss more than 25. The dead fish along the stream were not counted. No humpbacks were seen among the dead at the mouth of the stream; one live one was seen by me and three by others, in the creek itself. All other salmon seen were reds.

Returned to shore of Karluk Lake; inspected the beach line to the north of Thumb Creek. For 500 yards the salmon were scattered along the beach, spawning in the gravels. These were all red salmon. We waded among them and examined carefully and could not discover a single humpback.

August 20.—At the head of Thumb Lake, at mouth of inlet, 75 or 100 red salmon were schooled off the two entrances (a long sand island between) and were entering at intervals during our stay of two hours. In the creek itself very few salmon were seen, either dead or alive, and the dead fish were all old, as though no spawning had been in progress since the early part of the season. Lucas walked up the stream for about 3½ miles and came to falls, at the foot of which a small number of reds were gathered, making futile efforts to jump them. None were seen by him above the falls. During the walk he saw few dead fish. This must be considered a relatively unimportant spawning stream, yet it appears to have ideal spawning gravels and a good flow of water. The gravels continued, according to Lucas, for 2 miles or more, and for that distance a few reds were seen alive in the stream and dead along the banks. But above, the character of the stream changed. It became rapid and turbulent, and the bed consisted of rock slabs, with only occasional limited patches of gravel. Along this stretch saw no dead fish, and none living, until the falls were reached.

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A tributary comes out of a side valley (to the left, looking upstream) and joins the main stream near its mouth. Almost no live fish were seen in this creek, and no dead ones, although the gravels seemed favorable. On the flats above the junction of the two streams are a number of bayous with excellent spawning gravels, but these were mostly untouched.

No other important tributaries enter Thumb Lake. A small creek enters in the northwest corner, building out a delta of coarse stones, which projects to form a slightly prominent point of the shore line.

A limited amount of spawning was in progress off the mouth of this creek and for perhaps 100 yards above. Then the stream becomes very rapid, descending in short steps over coarse rocks and bowlders, in a little ravine. Apparently no salmon ascend beyond this point. As so frequently with these short and otherwise favorable streams, the greater number of the spawners must fall a prey to the bears. Well-beaten bear trails were everywhere, and wallows where they lie and devour the fish they have thrown out on the bank. Fragments of freshly eaten salmon nearly always testify to the presence of these bears immediately before (or at the time of) our visit.

The humpbacks were not found in Thumb Lake or tributaries, save for an occasional straggler. For the total population of the Thumb Lake, Thumb Creek, and tributaries, one red to five humps would be an approximation to the condition this year.

August 21.—Took dory up O'Malley River into the lake; surveyed the latter while Lucas and Studdert ascended the inlet as far as spawning fish were found. The inlet is a considerable stream with apparently favorable gravels. We observed a few reds off its mouth and in the creek, perhaps 50 to 75 in all, but the stream soon becomes unfavorable, traversing a hilly district with swift current and coarse slabs of rock. The watershed is short, an extensive valley to be seen beyond the near ridge that bounds its upper end evidently draining to the south. The part of the stream suitable for spawning probably is limited to the lower 200 or 300 yards. There were two mouths to the stream at the time of our visit, one on each side of a sandy bar thrown up by stream and lake. The eastern mouth was much larger, but red salmon were entering through each of them.

No other tributary of any importance enters O'Malley Lake, but the most valuable spawning stream of this watershed enters the outlet of the lake immediately below its emergence. It comes out of a valley to the east, enters O'Malley River from the left (looking upstream), and is the creek into which the majority of the fish were observed to enter last year, when we stood at the junction and tallied those coming up the river. A few continued into the O'Malley Lake, but the majority went into Falls Creek, as we have designated this stream. On inspection by Lucas, it was ascertained that the lower mile of this creek runs through the bottom lands and is well stocked with spawning fish, but beyond this the hilly country is reached, the stream grows boisterous, with a bottom of slaty rock, and practically no more fish were found. This continues for another mile, to a vertical fall of 20 feet, wholly insurmountable. Below the falls evidence of fish were found where bears had fed, and a few were seen all the way to the falls, but they were widely scattered.

In addition to O'Malley River, there enters at the head of the lake (i. e., Karluk Lake) a stream we call Canyon Creek, of real value. It comes out of an extensive valley to the left (facing head of lake) of the valley containing Falls Creek, and descends into the same, flat, swampy meadow land through which O'Malley River and the lower course of its affluent, Falls Creek, flow. Looking toward the head of the lake we see three valleys, occupying deep convergent clefts in the mountains. The right-hand one is occupied by O'Malley Lake and its main inlet, the middle one by Falls Creek, and the left-hand one by Canyon Creek. The latter enters Karluk Lake only 400 feet to the left of the mouth of O'Malley River, and is a beautiful, clear, cold stream in its lower course, with ideal spawning gravels. It was examined by Studdert, who reported that in its lower course, for about three-fourths mile, it meanders through a flat overgrown with tall, coarse grass, and the bottom is ideal for spawning. Then it enters hilly country, has a swift current and rocky floor, and carries but few fish. Along with Falls Creek it forms the principal spawning area of the head of the lake.

August 22.—Two short creeks (Grassy Point Creek and Halfway Creek), entering the west side of lake, were explored by Lucas and Studdert. Both are brawling streams, with coarse bowlder beds and only occasional very limited patches of gravel. They are only 10 to 15 feet across, but in spite of their small size and unfavorable character they carry more red salmon in proportion to

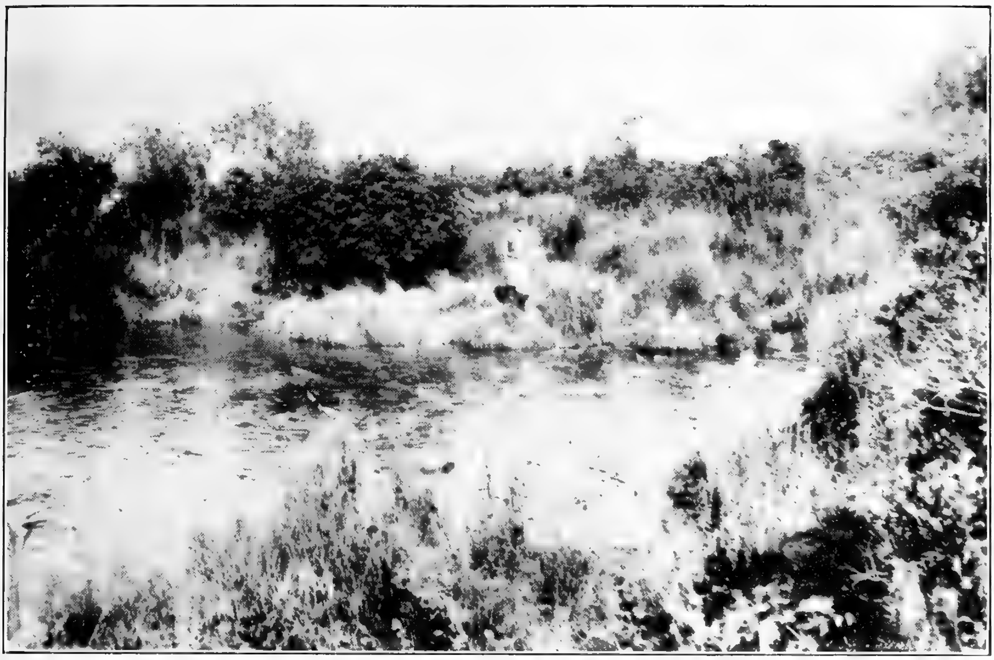


FIG. 12.—Lagoon at Little Lagoon Creek in July, 1926

FIG. 13.—Salmon densely massed in one corner of the lagoon at Little Lagoon Creek in July, 1926. These fish were congregated at the point where one of the small streams enters

Fig. 14.—School of salmon off the mouth of Little Lagoon Creek, 1926

Fig. 15.—Dead salmon in the lagoon at Little Lagoon Creek in August, 1926

their size than do the more suitable spawning streams of the Thumb and Head of Lake. Only about a mile of their course is suitable for spawning, sometimes even less. No humpbacks were seen in any of the short creeks on the west coast.

August 23.—Ran to head of lake. Lucas and Studdert examined Cascade Creek and Meadow Creek. At the latter fish were congregated off the mouth, entering at intervals. Perhaps 100 there, all told. Comparatively few dead fish. The stream was reported favorable for one-half mile, then rapid and bowldery, and fish dropped off, although no falls were encountered. The stream became so rough that in less than 2 miles the fish had disappeared.

As regards numbers of fish at head of lake, it seemed that, as nearly as we could estimate, the scarcity of red salmon this year is nearly equally distributed over all parts of the lake. Compared with 1921, the dead fish and the living were lacking in what appeared equal proportions. The rivers at the head of the lake were signally deficient, the sloughs in which last year the dead salmon had so greatly become aggregated were relatively poorly covered.

The shore spawning grounds about Cascade Creek, O'Malley River, and Canyon Creek were less populated, proportionally, than were the streams themselves. Along that stretch of beach to the left of O'Malley River, extending for a quarter of a mile, where last year a continuous band of spawners was closely crowded, contained this year only a few straggling pairs. But on the whole the situation seemed in harmony with our expectation, from the counting at the weir, that on the average there were only one-fifth the fish this year that we found last year.

A very few scattering humpbacks find their way to head of lake and enter streams. Probably less than a dozen, all told, were seen in O'Malley River and Falls Creek. None were observed spawning in the lake gravels.

August 24.—Ran down east shore, examining all streams below Thumb Bay. Cottonwood Creek had a few fish off mouth; occasionally one was seen to enter. Contrasts strikingly with last year, when there was a constant procession of salmon scurrying over the shallow beach. Perhaps 100 live fish in the first one-fourth mile of stream and comparatively few dead ones. Lucas and Studdert ascended stream into the canyon. Available spawning grounds in lower one-half mile only; above that no falls found, but rapid and impracticable.

Temperature at mouth Alder Creek 45° at 9.55 a. m., when lake temperature was 47° and air 54°.

The eastern shore of lake north of Thumb contains many shallow stretches of good gravels, in which spawning red salmon are working. The total number is small this year, but they are widely distributed. No live humps observed anywhere among beach spawners, but two dead ones seen on beach between Alder Creek and the Thumb. None were seen in short rocky streams on either side of the lake.

Spring Creek was again examined. *Very* deficient, compared with last year. Only some half a dozen live fish and practically no dead ones seen below ponds, and in the ponds themselves certainly not one-tenth as many, living or dead. *None* seen in the right-hand fork above junction with outlet of ponds.

Mouth of Spring Creek 41° at 12.45. Right-hand fork above junction 38°. Left-hand fork above junction 43°. All fish were in warmer left-hand fork. Last year we saw an occasional one ascending right-hand fork, but this year none were there. Temperature at upper end of upper pond, where water seems to enter at base of abrupt bluff, 40°.

Latter part of afternoon with Lucas, ran to head of lake and returned by way of Meadow and Tree Points. Temperature of Canyon Creek at mouth, 46°. O'Malley River at mouth 48°. Spawning gravels at upper end of lake 46°. Temperature of lake just outside entering current of O'Malley River 47°.

It will be seen that fish entering O'Malley River leave a temperature of 47° to enter one of 48°.

Fred R. Lucas, who had accompanied the writers on their visit to the lake in 1922, again examined the spawning grounds in 1924, and the following extracts are taken from his report:

Karluk.—The large humpback run in Karluk River did considerable damage to to the red-salmon spawn. On August 21 hundreds of thousands of fish died in the 20 miles of river between the weir and the still water at the Larsens Bay portage. The mortality included adult red salmon,

humpbacks, and trout, as well as young fish. The cause is unknown, unless it was due to overcrowding of humpbacks, with a possible fall of the water level in the river. Mr. Wood states that a few days later the river was still packed with live fish. It is estimated there were over 4,000,000 humpbacks passed through the weir this season.

Three men made a trip to Karluk Lake from September 16 to 24, inclusive. No unusual number of dead salmon containing spawn were seen above Larsen Bay portage, except in two creeks in the lake, as noted later.

Red salmon in considerable numbers had spawned and were spawning in the river from one-half to three-quarters of a mile below the lake, beginning at a point where the river makes a right-angled turn around the shoulder of a mountain.

It is believed, after viewing the river, lake, and spawning creeks, that only one-fourth to one-third of the humpbacks reached the lake. In the river the dead spawned-out humpbacks were piled in windrow after windrow, parallel with the stream, for its entire course.

Each creek is mentioned below in geographical order, starting at the outlet of the lake and going up the west side and returning on the east side.

Grassy Point Creek.—The first creek, going up the west side of the lake, just beyond Grassy Point. This creek did show unmistakable signs of some catastrophe to adult fish, similar to the lower river. Numbers of dead red and humpback salmon, that had not spawned, were seen in an advanced state of decay, yet not so far advanced as the ones in lower river. A few reds were spawning in the upper part of the stream; and some humpbacks were still alive in lower part, but spawned out. Judging from the distribution of dead fish and eggs adrift, most of the humpbacks stayed in lower part of stream, where is the best spawning gravel, and here is where the dead, unspawned fish were seen.

Halfway Creek.—Indications of a considerable number of humpbacks previously in this stream. No dead unspawned fish of either species. Several hundred reds spawning. Piles of dead eggs were in the creek. About two-thirds were humpback eggs. Red eggs were observed, that had been killed about the time they were to come out of the tender stage. Several dozen red eggs were noticed containing live fish past the tender stage. Quite a number of trout were in evidence. School of 200 reds was seen through the wall of breakers at the mouth of creek.

Meadow Creek.—This creek was well populated with spawning reds for about one mile. Judging from the dead fish, the creek was full of humpbacks a short time before. More than a dozen dead reds, full of eggs, were noticed, but no dead humpbacks. The reds were in a better state of preservation than the humpbacks in lower river. One thing noticeable in the piles of dead fish washed against rocks in the stream was that there would be two or three reds against the rock and then seven or eight humpbacks on top of them. These reds were spawned out.

Cascade Creek.—Very few fish of any kind have used this stream. Some dead humpbacks were seen one-fourth to one-half mile from the lake, and a few reds were spawning.

Beach at head of lake.—Large numbers of humpbacks have spawned here on top of a good many reds. Some other reds were spawning.

O'Malley River.—Red salmon were spawning in this stream in larger numbers than ever noticed before by the writer. Believe it would average a pair to each square yard, except in the so-called "pothole," where they had spawned earlier. Two visits in August in previous years disclosed comparatively few fish in this stream. Apparently the red spawning here is at its height in September. Thousands of humpbacks had spawned here and some red eggs had been dug out. The reds were now digging out the humpback eggs. Behind every rock and in every eddy piles of humpback eggs lay. Within 22 steps the writer counted 12 piles that would average 5 gallons to a pile; and behind a small island about 6 feet in diameter there were more than a 50-gallon barrel full of humpback eggs. These eggs were all dead; had been dug out and drifted around before passing the tender stage. A small percentage of red eggs was among them. In fact, more or less red eggs were noticed adrift in every stream where humpbacks had spawned. Upon examining the live red eggs, including those partly white, there were about the following proportions: Fifty per cent were well eyed, 25 per cent were fertile but in tender stage (most of them beginning to show white spots); and 25 per cent were not yet to the tender stage. The dead red eggs—that is, eggs that had turned entirely white—were more numerous than the live ones. All of these live eggs will probably be picked up by the birds and trout before they hatch and after the dead eggs decompose.

Falls Creek.—Stream coming in on left below O'Malley Lake. This stream was visited by walking over the ridge from O'Malley Lake to the falls. Did not see a live or dead red salmon in this stream during the upper two-thirds of the distance from falls, but humpback carcasses were thick almost to the falls. A comparatively small number of reds was spawning over the humpbacks in the lower part of the stream. Some reds had spawned here before the humpbacks, but the entire stream was, in the main, given over to the latter.

Small stream at head of O'Malley Lake.—A few humpbacks have spawned here but no reds were seen.

Canyon Creek.—This is the best red stream on the lake this year. Some dead humpbacks were at the lower end, but live and dead reds were thick all the way to the falls. Some of the early red eggs are being dug out by present spawners.

The Thumb.—Beach at head of thumb. Reds and humpbacks have spawned here in about equal proportions. Some reds are still spawning.

Thumb River.—More reds spawning here than in previous years. Conditions very similar to the similar stream at the head of the lake. Great numbers of humpbacks have spawned here and the reds are now busily working over the same ground. Humpback eggs, with some red eggs, were piled in heaps in eddies and shallows on the right-hand side. Apparently the humpbacks had dug up the early red nests, and what eggs were past the tender stage were still alive but drifting around.

Salmon Creek.—Found this stream well populated with reds. It had been even better populated with humpbacks and some reds earlier in the season, as indicated by eyed red eggs drifting around. One very small red was observed. A considerable portion of the live red salmon were small fish.

Upper Thumb River.—Both of these creeks had been seeded early by reds. Only bones were left in the water, but carcasses thrown out by the bears were thoroughly dried. A few live ones were still to be seen, especially in the left-hand or smaller branch. A considerable number of humpbacks had spawned. Trout were plentiful. Not many eggs were adrift.

First creek below Thumb on north side (either Alder or Cottonwood Creek).—Had more dead humpbacks than reds, with a few reds spawning now; also the usual number of humpback and red eggs on top of gravel. Humpback eggs in larger quantities and all dead; some red eggs eyed and alive.

Second creek from the Thumb (either Cottonwood or Moraine Creek).—This creek had at least six times more humpbacks than reds, with a few reds spawning now.

Spring Creek.—Evidently the humpbacks spawned mostly in creek below potholes. Red carcasses in potholes were not as numerous as two years ago. Digging in the gravel, discovered humpback eggs exclusively, up to the potholes; but in little lakes, especially the upper one, more red eggs than humpbacks. Very few live reds anywhere in this creek.

There were spawned-out humpbacks at every place where we landed around the lake. We were delayed two days on the lake by a strong wind and provisions were exhausted. Each creek was ascended as far as the fish could go, with two exceptions—the largest creek at the head of Thumb Lake and the second creek from lower end of Karluk Lake on the north [east] side.

The most extensive observations of the spawning in Karluk Lake were made during the season of 1926 by the junior author and a small field party. The greater part of the months of July and August were spent on the lake, which was carefully mapped and sounded. Some preliminary observations on the limnology of the lake were made, including both surface and deep temperatures on the lakes, temperatures of the tributary streams, and some few qualitative plankton collections were made. Other data bearing on the history of the eggs and of young salmon during their life in the lake were secured. Particular attention was given to the spawning of the adult fish, which was made especially interesting and important by the remarkably fine run and escapement of 1926. The spawning escapement was the best in many years, and in all probability was the best that has ever been observed by the few white men who have visited the lake. The notes made are too extensive to quote in full,

but the following abstract has been prepared, giving the observations bearing especially on the spawning:

July 12.—Very few fish in the river below the lake. About 100 spawning in a very small spring-fed stream that enters the lake from the west side, about 300 yards above the outlet. Temperature of this creek 39.5° F.; of the lake surface 52° F.

July 14.—Salmon spawning abundantly at the head of the Thumb, in Thumb River, and in Salmon Creek, which was explored up to the first impassable falls. Apparently every available spawning space was occupied in the river and in the creek. * * * At the head of the Thumb, near the mouth of Thumb River, and in the lower part of Thumb River the nests were as thickly placed as possible—one nest touching the next. Just below the mouth of Salmon Creek the salmon were collected in a dense school—they were packed in vertically, and the whole pool showed only a mass of noses sticking up above the surface. In the creek itself both live and dead salmon were numerous—estimated 1,000 to each 25 yards in the lower part of the stream. The dead salmon were apparently not long dead, as decay was not far advanced. About three-quarters of a mile of this creek is available for spawning. Estimated at least 15,000 fish in the creek, not counting those in the river outside. Estimated 5,000 in Thumb River and about its mouth.

July 15.—Halfway Creek. Two to three thousand fish spawning in the first two to three hundred yards. A dense school just off the mouth. Several hundred spawning on the beach, both north and south of the creek. Two or three hundred on a stretch of fine beach about 300 yards south of the mouth of the creek.

At the head of the lake estimated 4,000 salmon spawning alongshore, especially between the mouths of Cascade Creek and O'Malley River. Except in a few places, all available space seemed to be well covered. Dead fish were very numerous and had apparently spawned earlier than in Salmon Creek, as they were in a more advanced stage of decay. Many of the earlier spawning beds had been exposed by the receding of the water (a condition frequently noted throughout the season), and it was judged that spawning had taken place about two weeks before—i. e., about July 1.

O'Malley River and the lower parts of Falls Creek and Canyon Creek appeared to be populated to capacity, and there were dense schools just outside their mouths. * * * In O'Malley Lake, however, only very few salmon were to be seen. There were a few near the outlet and near the inlet, but there were not more than a few hundred in the entire lake.

July 16.—Little Canyon Creek. Although very small in area, the place was one of the most remarkable and interesting of any visited. A small pond or lagoon had been formed just back of the beach by two small streams that drain from the mountain side. The stream connecting the lagoon with the lake is not more than 25 or 30 feet long, and the lagoon is only 50 or 60 feet in width. The water was very cold, 45° F. in the outlet from the lagoon and 39° F. at the inlets, while the surface temperature of the lake was 59° F. The concentration of spawning salmon here was so great that it could hardly have been exceeded. Estimated 1,500 salmon in the lagoon, 2,000 just outside, and about 800 (counted roughly) dead on the beach just outside. They were spawning thickly in the lagoon, and equally on the beach, and for about 200 yards below Little Lagoon Creek, especially at places where there were small trickles of water entering the lake from the mountain side.

Estimated 2,000 salmon spawning in Big Bear Creek and on the beach south of Bear Point. Salmon spawning alongshore on both sides of Boulder Point.

Cottonwood Creek was examined hastily. Salmon were spawning in the creek and were thickly bunched off the mouth of the stream, so that the surface of the water was a mass of fins and noses.

Moraine Creek: Estimated 1,500 to 2,000 spawning fish in the first 100 yards; 1,000 to 1,500 were just outside the mouth, thickly schooled, as has been so often observed. Spawning was in progress for 300 to 400 yards along the shore of the lake below Moraine Creek, and it was estimated that there were about 500 salmon for each 100 yards. The water along this beach was somewhat cooler than the lake surface offshore, probably caused by seepage.

Spring Creek: Probably no salmon schooled about the mouth of Spring Creek, though there was a fair number spawning all along the creek and in the holes. Estimated 1,200 to 1,500 in all.

July 17.—Grassy Point Creek was examined for about 300 yards, and it was estimated that there were about 3,500 salmon in this distance. A large school was waiting just outside the mouth,

Fig. 16.—Dead salmon on the beach, early in August, 1926

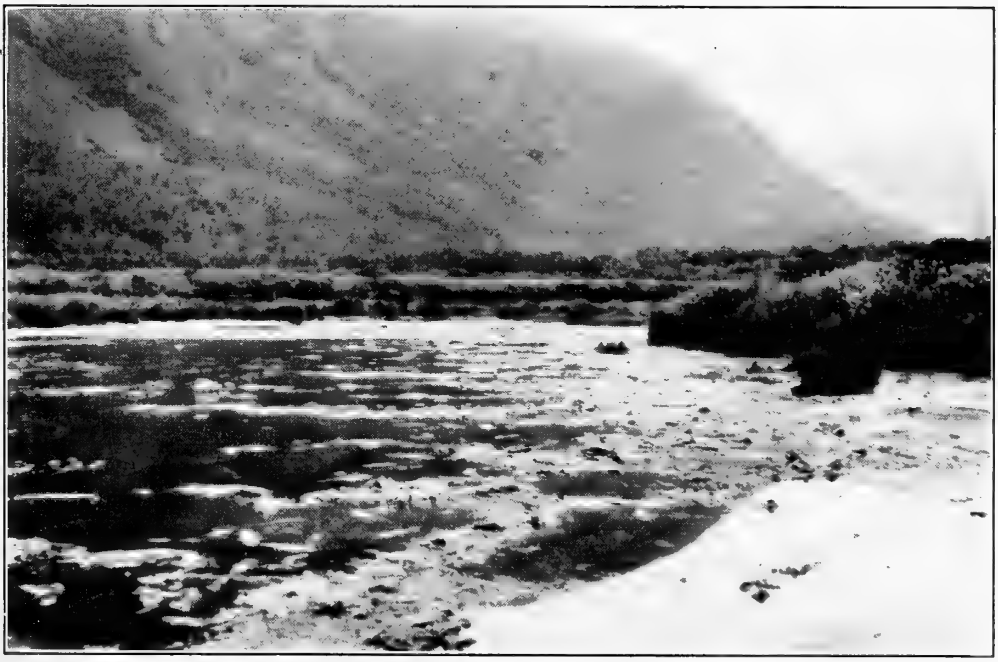


Fig. 17.—Lower Thumb River in August, 1926. Note the great numbers of dead salmon and the spawning beds exposed by low water

FIG. 18.—Lower end of Canyon Creek, August, 1926

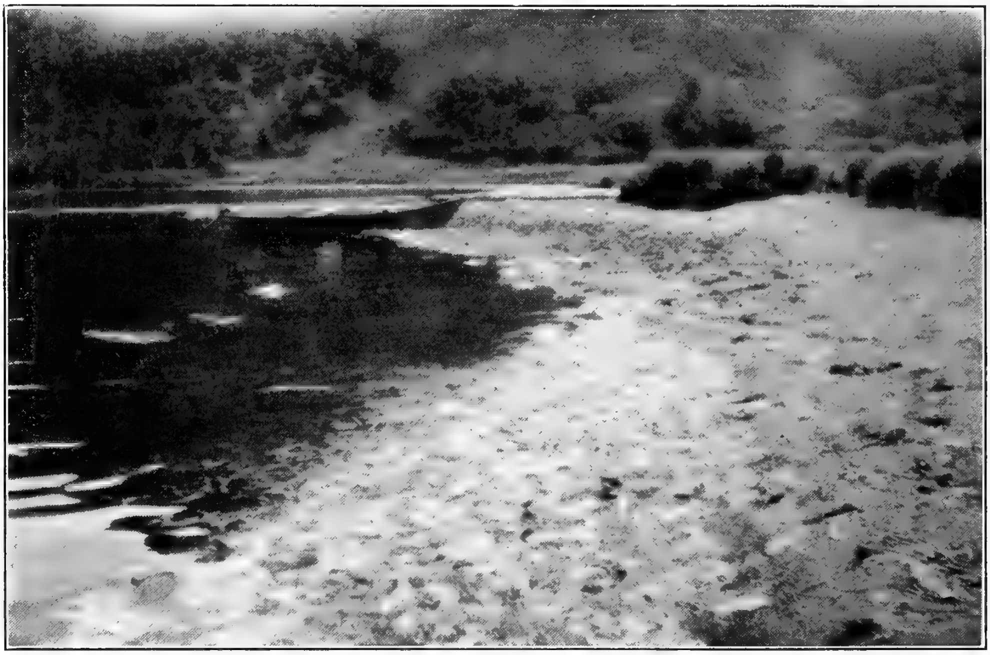


FIG. 19.—The beach at the head of the Thumb, late in August, 1926. The dried skin and bones of dead salmon left by the blowfly larvæ may be seen above the water line. The white streak, 6 or 8 feet wide, along the edge of the water is composed of the disintegrated bodies of dead salmon

and fish were spawning for about 150 yards north and 100 yards south. About 1,500 fish in all in the lake around the mouth of this creek. Very similar conditions were noted along the beach near Halfway Creek and at Meadow Creek. In Meadow Creek we estimated that 3,000 to 3,500 fish, spawning or dead, were contained in the lower 200 to 300 yards. Another thousand or 1,500 were schooled off the mouth or spawning along the beaches on each side of the stream.

July 18.—Spawning salmon were noted, though they were not numerous, along the south side of Grassy Point, the south side of Tent Point, and about the mouth of a small creek that enters the lake about 400 yards north of Tent Point. Others were noted along the shores near two small creeks that enter from the west side about one-half and 1 mile above the foot of the lake.

In Thumb Lake several thousand salmon were seen schooled in the lower end, where it narrows to the outlet, and all along the lower end to the north of the outlet. Thumb River, above the lake, was prospected for about 2 miles. The river branches about one-half mile above the lake. One branch (the main one) goes on in the same general direction as the part below the forks (i. e., toward the east), while the other branch comes from a valley to the north. At the junction, the north branch breaks up into several mouths, forming numerous small islands and deltas. This whole system of the upper Thumb River was crowded to its apparent capacity with spawning salmon. The gravel of the river bed was everywhere covered with spawning beds; apparently there was not a square yard of the whole river bed, wherever there was suitable gravel, that did not contain a spawning bed.

Toward the upper part of the south branch fish were not quite so numerous, but spawning conditions were not so favorable here, as the fall was becoming more rapid, with cascades and big slate bowlders common. Similar conditions were observed in the north branch, which is not quite as large as the south branch. All of the channels in the delta region were densely populated with spawning fish. If anything, the north branch was more densely populated than the south branch, though on account of the greater size of the latter it evidently contained more fish. Almost everywhere in both branches the live salmon were in rank after rank across the streams—one rank right behind another. There were tens of thousands of dead salmon strewing the banks and gravel bars. Any estimate of the number of spawning fish was difficult but it was thought that certainly not less than 300,000 fish, and probably about half a million, had entered Upper Thumb River up to this time. This year (1926) there was no single spawning area as important as this one. It accommodated about half of the heavy early escapement, as well as a fair proportion of the later runs.

The small creek entering Thumb Lake near the northwest corner was examined for a few hundred yards, as far as salmon can ascend. There were 700 to 800 fish in the creek, about 500 dead along the shores of the lake, and some 1,500 massed in a typical dense school off the mouth of the stream and spawning along the foot of the lake on both sides.

July 19.—A few spawning fish were seen at the first point above Island Point on the east side of the lake. There is no creek here, but the topography indicates that there may be some drainage seeping through the gravel. A few were seen at scattered points along this shore, up to the head of the lake, but the total number was inconsiderable—probably not more than a few hundred.

Canyon Creek was examined for about 2 miles. Great numbers of fish were spawning here, though apparently they were not quite as numerous as in Upper Thumb River, nor was there quite as large a spawning district. At one place there was a fine large hole in the river, approximately 6 feet deep, 30 feet wide, and 60 feet long, which was filled with salmon. Estimated 4,000 to 5,000 in this one spot, and between 100,000 and 150,000 in the whole stream. At the upper limit of the part explored the creek goes through a rugged, steep-walled canyon, in which is a fall that is almost but not quite insurmountable for salmon. We watched many fish trying to get up over the fall, but saw none succeed, although a few were seen above. This is doubtless practically the upper limit of the spawning area in this stream.

Falls Creek was explored for about 1½ miles. No insurmountable falls were reached, although the upper quarter of a mile was a series of cascades, and here fish were relatively scarce. Estimated 20,000 to 25,000 fish in the entire stream, which is considerably smaller than Canyon Creek.

There are a number of small spring branches to O'Malley River, which enter between Falls Creek and Karluk Lake and which provided spawning areas for a large number of salmon. One, alone, had about 5,000 fish, both dead and alive, and it was estimated that in all there must have been twice that number.

August 1.—At Halfway Creek only a very few hundred salmon were to be seen. These were about the two mouths of the stream and spawning along the beach for about 100 yards on each side. There were many dead fish in the creek and along the beach, far advanced in decomposition—much further decomposed than on our previous visit. * * * There appeared to be comparatively few fish in the creek above the mouth.

August 3.—Thumb River, where it enters the Thumb, is quite a different looking stream now as compared with two weeks ago. Comparatively few fish were to be seen, though the shore on each side of the mouth of the river was covered with carcasses in advanced stages of decay. * * * Many dead salmon are to be seen all along the shores of the lake, even where, for a mile or so, no spawning had been in progress.

August 4.—In the streams at the head of the lake comparatively few live salmon were to be seen, even in Cascade Creek, O'Malley River, and Falls Creek; but dead carcasses lined the shore at the head of the lake, though in places remote from any spawning areas. Along the shores of Camp Island there were dead salmon, averaging about one every 10 feet, and at places more abundant than that.

August 5.—On a visit to the foot of the lake it was noted that live salmon were scarce, as usual, but there were many dead ones. The shore all along the foot of the lake, from Spring Creek to the outlet, was thickly covered with decayed remains of spawned-out salmon and with the skins and bones left after the myriads of blowflies had done their work.

August 6.—There were only about 100 fish spawning in Little Lagoon Creek, although the lagoon was literally choked with dead salmon.

August 7.—Moraine Creek was explored for about 1 mile. There were lots of dead salmon as far as we went, but very few live fish—probably not more than 1,500 to 2,000 in the whole creek. There were salmon still above the highest point we reached, but the creek became much steeper within the next few hundred yards. We estimated that 10,000 to 15,000 fish had spawned here up to this date.

August 8.—A new run of fish was noted in O'Malley River. These were clean and bright, and many had not yet acquired the bright red spawning dress. Only a few of the earlier run remained alive, * * * the vast majority of the tremendous numbers we saw three weeks ago were dead and their carcasses rapidly disintegrating. There were several thousand of these fresh-run salmon along the foot of O'Malley Lake. They were in shallow water but were not spawning. A few dead females observed in O'Malley River and along the foot of O'Malley Lake were quite green, and it was evident that the new run was not yet ready for spawning.

About 1,000 fish were schooled in Karluk Lake, just outside the mouth of O'Malley River. About the same number were schooled off the mouth of Canyon Creek, and a few were in the creek itself. The same conditions were noted in Falls Creek, Cascade Creek, and Meadow Creek, which contained a few live fish, apparently mainly of a fresh run, and multitudes of dead salmon piled up in great masses against the larger bowlders, lining the banks, and rapidly disintegrating under the influence of decay and blowflies. Fish were spawning along the beach at the head of the lake.

This fresh run of fish was apparently the beginning of the second heavy run into the Karluk River. This run begins late in July, and in one day some 37,000 had been counted through the upper weir, located at the Larsen Bay portage, just a few days before these were seen at the lake. During the last few days of June and most of July the average daily escapement had been less than 10,000. Confirming this interpretation is the fact that the new run, wherever noticed, was composed of fish that were distinctly larger than the fish that entered Karluk River in June and spawned during July. The careful measurements made of daily samples of fish taken at the mouth of the river show clearly this increase in size. (See the section entitled "Analyses of Recent Runs.")

August 9.—In Thumb River there were only a few thousand live fish left in the whole system. * * * A few fish, apparently of the new run, were to be seen about the mouth of the river, in Thumb Lake, and in the stream itself, but there was no great showing of live fish anywhere. Only at one place in the upper river, where a short stream entered from a large spring, were the fish at all thickly schooled, but even here there were only a few hundred.

August 14.—About 100 fish, apparently newly arrived, were seen off the mouth of Moraine Creek.

August 16.—Several hundred fish were schooled off the mouth of O'Malley River, and about 2,000 were spawning in the river. Some of the fish observed on the eighth, at the foot of O'Malley Lake, were spawning, but the majority were still waiting and were massed in close schools in shallow water, close to shore where drainage from springs cooled the water. * * * About 1,000 were dead along shore. Between 1,000 and 1,500 fish were seen in the creek that enters at the upper end of O'Malley Lake. Most of these were dead, though there were a few hundred live ones in the creek and in the lake about its mouth.

August 22.—Comparatively few live salmon were found in Upper Thumb River—estimated 10,000 to 20,000. There were a few hundred about the mouth of the upper river. In the river below Thumb Lake, however, salmon were more numerous than they had been since the heavy spawning in July. The number here was estimated at between 1,000 and 1,500. A few were schooled off the mouth of Salmon Creek, but no such number as in early July.

August 23.—Halfway Creek was explored as far as the first falls that are impassable for salmon The available portion of the creek is only about a quarter of a mile in length. About 1,200 to 1,500 fish were spawning here, and it was estimated that not less than 5,000 had previously spawned and died.

Grassy Point Creek was less well populated, although about ½ mile is available for spawning. Estimated only 300 live salmon here, largely confined to the lower two-thirds of the stream. Estimated that between 5,000 and 10,000 had spawned here during the early run.

Spring Creek contained very few fish. A dozen or so were seen off its mouth, and about 75 in the stream and the spring pools. Moraine Creek was examined for only a few hundred yards and contained virtually no spawning fish. Only 7 live salmon were seen in the creek, and a dozen or so were in the lake about the mouth.

Cottonwood Creek was explored to the first impassable falls—about a half mile. Estimated that 5,000 to 10,000 salmon had spawned here earlier in the season, although on this date there were only some 500 live fish in the stream and about 200 schooled in the lake near its mouth.

Little Bear Creek is a small, spring-fed stream of much the same character as Spring Creek. It rises in several shallow pools, averaging 25 to 30 feet across, which are used to a limited extent by the spawning salmon. It was estimated that several hundred salmon had spawned here, but no live ones were seen. A few dozen were in the lake just outside.

August 24.—A few dozen fish were seen off the mouth of Salmon Creek, but there were very few fish in the creek itself. Only about 50 were counted in the first 200 yards.

Thumb River, below Thumb Lake, contained a number of salmon, estimated at between 1,500 and 2,000. They were spawning there and not passing on up the river. About 800 salmon were spawning along the shore at the head of the Thumb on each side of the mouth of the river.

Big Bear Creek: This is similar in character to Spring Creek and Little Bear Creek, but is larger than either, containing two or three times as much spawning area. It was estimated that about 1,000 salmon of the early run had spawned here, but there were only a few dozen live fish on this date.

Willow Creek is another steep, bowldery stream, similar to Cottonwood, Grassy Point, Halfway, and Meadow Creeks. Quite a number of fish were schooled off the mouth and some were spawning along the beach, the total number being estimated at 200. This stream is passable to salmon for about a quarter of a mile. There were about 400 live fish in the creek, and it was estimated that 4,000 to 5,000 had spawned here previously.

O'Malley River: Five hundred to 1,000 fish were schooled off the mouth, and about 1,000 were spawning in the river between Karluk and O'Malley Lakes. The fish previously noted were spawning all along the shore at the foot of O'Malley Lake.

Falls Creek: The scene here was typical of most of the streams at this time—many dead fish almost completely decomposed, the water foul with refuse from the carcasses, and comparatively few were congregated in the holes.

Canyon Creek: One thousand two hundred to 1,500 live fish were observed in the lower half mile, and a dense school containing several hundred was off the mouth of this stream.

Salmon were spawning all along the beach, from a little distance east of the mouth of Canyon Creek to Cascade Creek. They did not appear to be very abundant, however. * * * Estimated about 1,000 in all.

Cascade Creek: This was relatively more densely populated than most of the other streams. The stream was explored for about three-quarters of a mile. Above the first quarter mile the stream rises rapidly, flowing through a precipitously walled canyon. Spawning fish were seen as far as we went, but there the bed of the stream became still steeper and it is doubtful that many fish were above. It was estimated that there were 2,000 to 2,500 fish in the stream.

Meadow Creek: This stream was explored for about 500 yards. Only about 500 live fish were seen and about ten times as many dead ones.

This completed the observations on the lake spawning grounds for 1926. It is apparent from the notes that the spawning during the latter part of August was remarkably light, especially in view of the fact that there was a heavy escapement through the weir during the month. The following note made on August 24 bears on this:

Many salmon have been seen during the past few days, jumping and "porpoising" in the lake tself—alongshore and out over the deeper water. It seems probable that these are waiting in the lake to ripen before seeking the mouths of the streams. Certainly we have seen no such numbers in the streams as have been counted through the weirs during the past month.

However, during the trip down to the portage, on August 27, great numbers of salmon were also seen in the river below the lake. Evidently, many of the fish that entered the river during August had remained in the river. The river was examined on August 10 and was found to contain only a few fish, but on the 27th "we saw fish everywhere in the river. * * * In the first 2 miles below the lake they were very numerous, and many of them were spawning. However, this was by no means true of all the fish in the river, as we noted fish entering the lake at the outlet, and there were many quite obviously passing upstream below the region where the fish were spawning. Under these circumstances it was difficult to estimate the number of fish actually spawning in the upper 2 miles of the river, but I believe there were between 50,000 and 100,000. In addition, there were as many more, approximately, in the river passing up, either to spawn in the upper reaches of the river or to go on into the lake."

The summer of 1926 was exceptionally dry throughout most of Alaska. This was not only a matter of common observation but is shown in the records of the Weather Bureau. Throughout the Karluk System the streams were very low, probably lower than they had been for many years. The lake, too, was noticeably lower, the level late in August being about 1 foot below what appeared to be the normal level, judging by the grass and other vegetation alongshore. Just what effect this will have on the success of the spawning is problematical; it may be slight or it may be great enough to offset in considerable measure the effect of the fine spawning escapement. On August 9 the following notes were made:

In Thumb River, where the spawning had been heaviest, many of the nests were exposed by the lowering of the water. We dug in some of them and found mainly dead eggs, although a very few live ones were found.

Similar conditions were noted in all of the larger streams—O'Malley River, Falls Creek, and Canyon Creek. All of these flow for a considerable portion of their lower courses through flats, where the stream beds are relatively wide. All of the other streams, except those small ones of the character of Spring Creek, drop down much more abruptly from the mountains, and the beds are more closely confined. These, therefore, were not as much affected by the dry season.

Perhaps associated with the dry season, there was a noticeably heavy mortality among the unspawned fish in 1926. This was observed throughout the season and in all the spawning streams. On July 18, in Spring Creek, "it was very noticeable that many of the females were not completely spawned out; 6 of 12 examined had eggs apparently still in good condition. Most of these were apparently not spawned at all, although ripe." On the same date, in upper Thumb River "we saw many dead females, ripe but unspawned, and many others that were not completely spawned out. Causes of death quite unknown, as most of them appeared to be in fine condition." On August 16, at the foot of O'Malley Lake, there were "about a thousand dead [salmon] alongshore and * * * all the dead females had apparently died without spawning and before the eggs had ripened; roe still solid." These, of course, were the late run mentioned above. Similar observations were made frequently during the summer, and the general impression given was that about 25 per cent of the females that reached the lake died only partially spawned out. This is strikingly different from the conditions observed by both Rutter and Bower, mentioned above, both of whom reported nearly all of the females as spawning completely. In 1924 Mr. Lucas noted the death of large numbers of unspawned salmon in Grassy Point Creek, but specifically states in his notes that dead unspawned fish were *not* found in several of the other streams. It is apparent that the death of unspawned fish in 1926 was quite unusual. This may have been due to low water, the crowded conditions on the spawning beds, a combination of these two, or to some other cause.

LIFE HISTORY OF KARLUK RED SALMON

The run of red salmon to the Karluk River extends over a period of about five months, beginning in May and ending in October. The commercial fishing season for the years 1916 to 1926 is given in Table 2.

TABLE 2.—*Fishing season at Karluk, Alaska, from 1916 to 1926*

Year	Began fishing	Stopped fishing	Year	Began fishing	Stopped fishing
1916	June 3	Oct. 2	1922	June 5	Sept. 19
1917	June 4	Sept. 27	1923	June 8	Sept. 15
1918	June 10	Sept. 28	1924	June 1	Sept. 30
1919	June 6	Sept. 25	1925	June 15	Sept. 10
1920	May 26	Sept. 27	1926	do	Sept. 15
1921	June 15	Sept. 24			

The first fish to appear are, in general, well advanced toward spawning and certainly do not linger long in the lake before seeking the spawning gravels. The earliest spawning has not been observed, but it is believed to take place not later than the middle of June. From that time until late in the fall uninterrupted spawning is in progress in suitable gravels about the shores of the lake and in all favorable tributaries.

The spawning grounds have been visited frequently in the middle of the season, when, in favorable years, the tributaries are thickly lined with dead and dying fish, many of the dead even then in the last stages of decay. At the same time, spawning is actively in progress, and a constant procession of new arrivals from the lake is prepared to work again every available stretch of gravels. Undoubtedly the late

comers dig up many of the nests of those that came earlier, and destroy a regrettably large number of eggs; but they replace those they destroy with fresh lots of their own eggs, and many of the earlier eggs must escape destruction. Even in years of very heavy runs, when waste of eggs is excessive, the net result is probably a more complete seeding of all available gravels than occurs during runs of more moderate dimensions. It may well be that a spawning escapement beyond a certain size entails an economic loss. The increase in numbers of progeny produced by such overplus of spawners may not compensate for surrendering the economic value of the parents; but we have no evidence that "overseeding" of the beds ever occurs, with a diminished run in consequence. That the reverse is the case, we have a certain amount of evidence, and need only refer to the quadrennial run on the Fraser River, which persisted throughout historic times despite almost incredible crowding of the spawning grounds during the "big years." The more moderate spawning of the intermediate years produced only the limited runs of those years; and when finally the spawning escapement of a big year, because of a catastrophe, was during one season reduced to a fraction of its usual size, the big run disappeared completely and has never been restored.

As bearing on this point, we have in evidence also the large and small runs of pink salmon (*Oncorhynchus gorbuscha*), which occur in alternate years in virtually every portion of its range. The pink salmon matures invariably in the second year of its age. All the members of any run have developed from eggs laid down during the second year previous. Every big year, then, produces a big year, although with this species especially, the streams are crowded to capacity and beyond during years of heavy run. The waste here again is enormous, and the economic phases of the question may well be taken into consideration; but it is well to keep in mind that the net results of such excessive crowding of the streams are in the way of increased runs. To those, therefore, whose duties lie in the examination of spawning grounds, we recommended a certain hesitancy in certifying that the beds are "fully occupied" by spawners or are "overseeded."

During the summer of 1926 the ovaries from a number of females were preserved and the eggs counted to determine the number produced by each female, and from this the number that may be deposited on the spawning beds. The ovaries from 40 females were thus studied, the work being done by S. P. Smith, temporary scientific assistant. From each of the two ovaries found in each female a portion weighing 5 grams was taken and the eggs counted. Then the entire ovary was weighed and the number of eggs calculated. The results are given in Table 3 and are shown graphically in Figure 20.

TABLE 3.—*Number of eggs in Karluk River red salmon taken September 15, 1926*

Average length, centimeters	Number of individuals	Left ovary	Right ovary	Total	Average length, centimeters	Number of individuals	Left ovary	Right ovary	Total
53	1	1,320	1,510	2,830	61	10	1,884	1,917	3,801
54					62	8	2,039	2,018	4,058
55	1	1,645	1,310	2,955	63	4	1,828	1,915	3,744
56					64	1	2,085	2,750	4,835
57	2	1,600	1,682	3,282	65	2	1,975	2,019	3,994
58	1	1,328	1,030	2,358	66	1	1,735	2,509	4,244
59	3	1,818	1,837	3,655					
60	6	1,748	1,739	3,487	Average				3,728

It is apparent that the larger females have the greater number of eggs, the relationship being such that a difference of 1 centimeter in the length of the fish is accompanied, on the average, by a difference of 150 in the total number of eggs. The average of 3,728 is considerably higher than the number of eggs taken from red salmon as reported by fish culturists. The average number of eggs per female, as reported in the records of the hatchery formerly operated by the Alaska Packers Association on the Karluk River, is approximately 2,900. This discrepancy is doubtless due to the failure, in routine hatchery operations, to secure all of the eggs

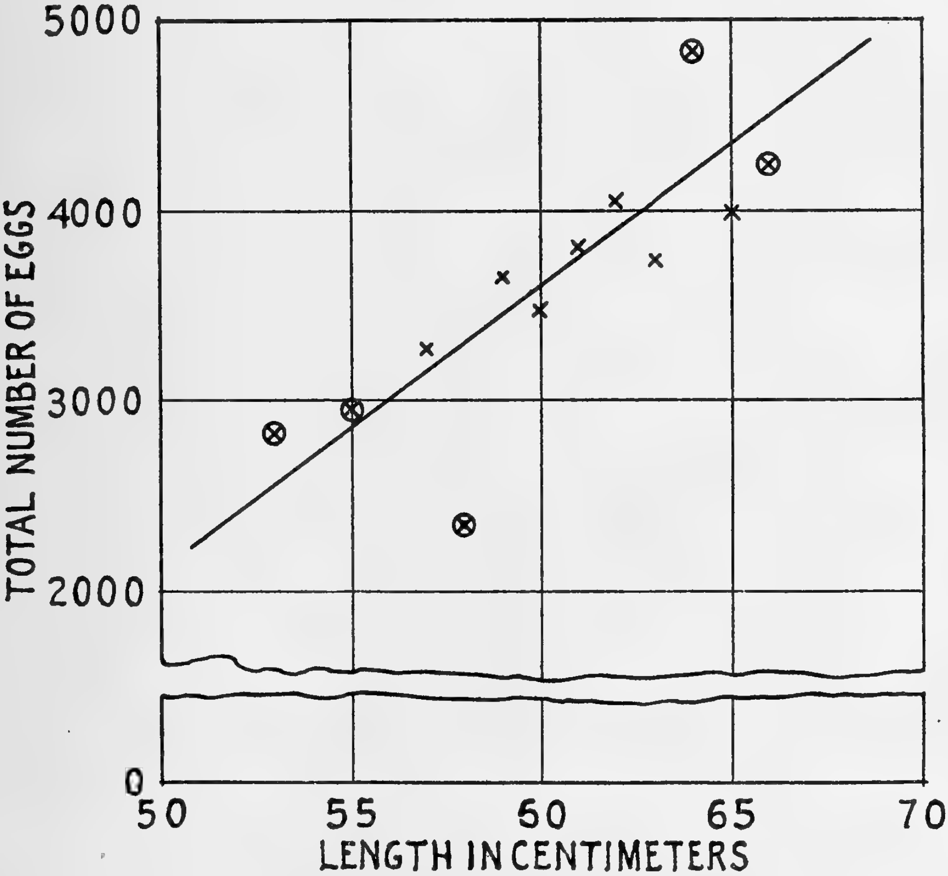


FIG. 20.—Number of eggs in Karluk River red salmon taken on September 15, 1926. ⊗, data from single individual.

produced by each female. Some may be lost before the artificial spawning takes place, and others may be left in the body of the female, especially if she is not perfectly ripe. The data secured by Chamberlain[9] indicate in the Karluk race an average number of eggs per female of 3,500—approximately the same as our figures.

These figures are especially interesting as indicative of the enormous number of eggs deposited on the spawning beds of Karluk Lake in a favorable year. It is probable that more than 1,000,000 females entered Karluk Lake to spawn

[9] See footnote 4, p. 9

during the season of 1926. This would represent over 3,000,000,000 eggs. Many of the females, however, died after entering the lake but before spawning, and many others died before depositing all of their eggs. It seems safe to say, however, that well over 1,000,000,000 eggs were deposited in the gravels of the lake and of the streams tributary to the lake. Of this tremendous number comparatively few survive even to make the seaward migration. The fate of those that do not survive, and the factors that affect, favorably or otherwise, the survival of the eggs and young fish during their life in fresh water, are questions that can not be answered now and are to be considered in the future study of the Karluk salmon.

The period of the hatching of the eggs and the time of emergence of the fry from the gravels is another subject that awaits investigation in the Karluk. That these are virtually controlled by the temperature of the water is well known; and from such data as we possess it is considered highly probable that the first fry to emerge make their appearance not earlier than the following spring and consist largely of those that, as eggs, were deposited earliest in the preceding summer. Following these there may well be a continuous emergence of fry during all the summer months, maintaining an order in their appearance corresponding roughly with that in which the eggs were laid down during the previous season. It has been observed elsewhere in western Alaska that fry of the previous season's spawning, with yolk sac still attached, could be found at the very end of the season. These were doubtless derived from the latest eggs to be laid the preceding fall.

The young remain in Karluk Lake for a comparatively long period and during this time make a sturdy growth. So far as known to us, none leave the lake on their seaward migration before the spring of their second year, and even these are few in number and form a negligible proportion of any brood. The great majority pass down the river and out to sea in the spring of their third year, while a smaller number remains in the lake until the spring of their fourth year, and an occasional individual until the spring of its fifth year. Random samples were collected in the spring of 1926 on five different days, extending from May 30 until June 12, comprising in all 619 individuals. Of these, 1.6 per cent were in their second year (see fig. 21), 74 per cent in their third year (fig. 22), 24 per cent in their fourth year (fig. 23), and 0.4 per cent in their fifth year (fig. 24). The youngest group averaged 96 millimeters in length, the 3-year group 135 millimeters, the 4-year group 144 millimeters, and the 5-year group 169 millimeters long. Of the total number, 314 were males and 305 females.

In addition to the classes above enumerated, which comprise the regular seaward migration of fingerlings, there are found in the river in spring and early summer a limited number of fry in their first year, which are believed to straggle out to sea during the early part of the season. Apparently they are not moving downward with the regular seaward migration of lake fish, but are observed even after the fingerling migration is past, in the eddies along the banks of the river and among the water weeds along the shore where the current is slack; but they seem to have disappeared before midsummer, and have doubtless gone to sea. The origin of these fry has not been traced, and it is not known positively that none of them have come out of the lake at this early age; but as considerable numbers of adult salmon are known to spawn in the river gravels below the lake it is considered probable that

the fry in question have had this origin and that they occur numerously. If this is true, their mortality in the sea must be extraordinarily great, for there are relatively few mature fish returning to spawn that have had this early history. In the 1926 run of mature fish only six-tenths of 1 per cent belonged to this group, which passes out to sea in the early fry stage before the formation of the scales, and the adult scales of which do not, therefore, record any growth in fresh water.

The seaward migration of Karluk fingerlings is a notable sight. At the mouth of the river they are first observed late in May, the wave of migration reaching its height and commencing to recede during the first two weeks of June. Where they first encounter brackish water (in the lagoon at the mouth) they are seen on every side leaping high in the air, with flashes of silver, rehearsing in miniature the leaping habit of the adults when they first taste fresh water on their return from sea at time of spawning.

At the time of their downward migration the Karluk fingerlings are unusually large and form a sturdy stock. They can well be expected to give a good account of themselves during their life at sea and should escape their enemies in larger measure than do the smaller fingerlings of many other streams. Their large size is partly due to their long residence in Karluk Lake, partly, no doubt, to the unusually favorable conditions for growth which they find in this watershed, and partly, perhaps, to a racial habit of vigorous growth, which they may possess independent of external conditions. In so far as their large size and consequent high survival value is determined by length of residence in fresh water, these desirable qualities may have been dearly bought, for it is an open question whether the serious reduction in numbers that must accompany an additional year or two of residence in fresh water may not outweigh the advantages that the survivors experience through increase in size. Those who have seen the hordes of trout and other predatory forms that infest river and lake and daily take their tremendous toll of young salmon during the entire period of their life in fresh water find it difficult to believe that mortality during this period is less than it would have been if spent in the sea. Sea life certainly has the advantage of inducing more rapid growth, with the result that the relatively defenseless stages are passed through more rapidly. We can be sure that a racial habit of migrating seaward predominately in the spring of the second year instead of during the third and fourth years, as at present, would produce vastly larger schools, consisting of migrants of smaller size. What the net results would be, compared with the present procedure, we have no facts to determine, but we look hopefully to the results of further investigations along the lines now planned. The Chignik fingerlings are much smaller when they seek the sea than are those of the Karluk race. If we can succeed in estimating the numbers of downstream migrants in the Karluk and Chignik Rivers over a term of years and can establish the average proportion of each that returns at maturity, we shall have important evidence bearing on this problem.

The problem itself is of more than academic interest, and in a modified form possesses great practical importance. More and more, in recent years, the salmon hatcheries have employed their funds in increasing their pond capacity and in feeding and rearing the young to larger sizes before liberation. It is a moot question whether funds thus employed produce larger net results than they would produce if used to

liberate larger numbers of young at a smaller size. In this, also, we are without facts to determine the problem. In one important respect the advantage would seem to lie with hatchery practice, for in pond life the young are protected from predaceous enemies and would appear thus to enjoy a signal advantage over wild stock spending an equal time in fresh water; but this is not the whole story, for the pond-reared fish are in turn exposed to certain dangers, due to crowding in limited quarters and to prolonged artificial feeding, from which the wild stock are exempt. No reliable statistics are available concerning the mortality incident to pond culture. When these have been secured we shall have made a beginning toward the solution of this most important problem in fish propagation.

As is true generally with the young of the red salmon, those of the Karluk race disappear on reaching salt water and roam the seas without detection until, after having spent varying periods in the ocean, they seek the river once more at spawning time. As will appear below, they mature at various ages ranging from 3 to 8 years, spawn but the once, and then perish. The list of the various age groups follows, considered in connection with the classes of fingerlings from which they develop.

These classes are five in number, as has appeared from the above sketch of their history, and are based on age at time of migration. They will be numbered from 1 to 5, the No. 1 group comprising the migrant fry in their first year, and the groups numbered from 2 to 5 representing those that migrated in their second third, fourth, and fifth years, respectively. This division will reappear in our analysis of adult runs and will form the basis of primary groups founded on length of residence in fresh water before migrating to sea. The secondary divisions are based on the number of years spent in the sea before maturing, and this varies in each primary group. Thus, the members of group 1, both males and females, mature and return to the river either in their third year of sea feeding or in their fourth. As they entered the sea during their first year after hatching, they are in their third or their fourth year at time of maturing. We designate these two age groups by the symbols 3_1 and 4_1, the first figure in each case representing the age at maturity, and the second the year of its life in which it migrated from fresh water.

The members of group 2 likewise mature in their second, third, or fourth year in the sea, and are therefore in their third, fourth, or fifth year of age at maturity. They are here designated as the 3_2, 4_2, and the 5_2 age groups (figs. 31 and 32).

Group 3 comprises the great majority of the youthful migrants, and furnishes the largest age groups among the adult fish. A rare individual of this group, always a male fish, is known to mature during its first season at sea while still in its third year, having spent but a few months on the sea feeding grounds. These diminutive "grilse" range from 30 to 40 centimeters long; and as they readily pass through the meshes of the seine used in the capture of the commercially valuable part of the run, they easily escape notice. (See fig. 25.) A larger size of grilse, belonging to group 3, is one year older than those above mentioned and returns in its second season in the sea as 4-year fish. These are still largely, but not exclusively, males, and are undersized fish of little value. The members of group 3 do not attain their full size and become commercially valuable until their third year in the sea, when they are in their fifth year. (Fig. 28.) The great majority of them always mature at this age, and they constitute always the great bulk of the commercially valuable run. A

smaller proportion remains at sea for one additional year, returning in their sixth year. (Fig. 30.) Group 3 gives rise, therefore, to four age groups, which we will designate as the 3_3, 4_3, 5_3, and 6_3 groups, the first figure in each designation giving the age at maturity and the second figure the number of years' residence in fresh water.

Group 4 is the second in point of abundance among the migrating fingerlings and furnishes correspondingly abundant classes in the mature run. Here, again, as in Group 3, a certain small proportion matures precociously and the fish are undersized and of little or no value, to which the name grilse is applied. Two age groups are present among these grilse, corresponding to the two described above in Group 3. The first of these matures during the first season in the sea and the members of it are exclusively male fish under 40 centimeters in length and wholly valueless, although in the fourth year of their age. (Fig. 26.) The second group is one year older, as the fish mature during their second season in the sea, when in their fifth year. In this group, also, the males greatly outnumber the females, but in less degree than in the corresponding class of grilse in Group 3. The most valuable contribution that Group 4 makes to the mature run is the fish that return in their third year of sea life, at the age of 6. (Fig. 29.) Although much less numerous than the 5_3's, they form a material part of the commercial run. Relatively few members of Group 4 remain at sea an additional year and return as 7-year fish, and we have encountered but one individual captured in the fifth year of sea feeding at the age of 8. Group 4 gives rise to five age groups, which we designate as the 4_4, 5_4, 6_4, 7_4, and 8_4 groups. Only the 6_4's have any considerable value.

Group 5 is the least numerous of all and is encountered only rarely among fingerling migrants or in the adult runs. Their greater age on reaching the sea seems to predetermine them to earlier maturing after a shorter period of sea feeding. A few diminutive male grilse that return after a few months in the ocean have come to our attention. (Fig. 27.) These were exclusively males, as in the corresponding classes of grilse in Groups 3 and 4. We have also encountered a few others (also males) that matured in their second sea year at the age of 6, and a small number of full-sized fish in their third sea year, at the age of 7. The 12 individuals of the 7-year group comprised 3 males and 9 females. If further experience with this group shall demonstrate an equally high percentage of females, this will furnish an interesting commentary on the high percentage of the males in Group 5 that mature precociously. This group gives rise to but three age groups, which we here designate the 5_5, 6_5, and 7_5 groups, all of which are without commercial importance.

From the above sketch it is apparent that while the length of the period that the young spend in fresh water has a certain influence on the age at which maturity is attained, the most important factor governing growth is the length of time spent in the sea. Full-sized adults, with females as numerously represented as the males, are produced in the Karluk race not before the third year of sea feeding, whatever the age or size of the fingerlings at the time of the seaward migration. Many individuals mature and return to spawn and die having had less than three seasons in the sea, but these are always markedly undersized, conspicuously deficient in color of flesh and amount of oil, and they develop in minor degree the secondary sexual characters that mark the species. They are largely male fish and are known as grilse.

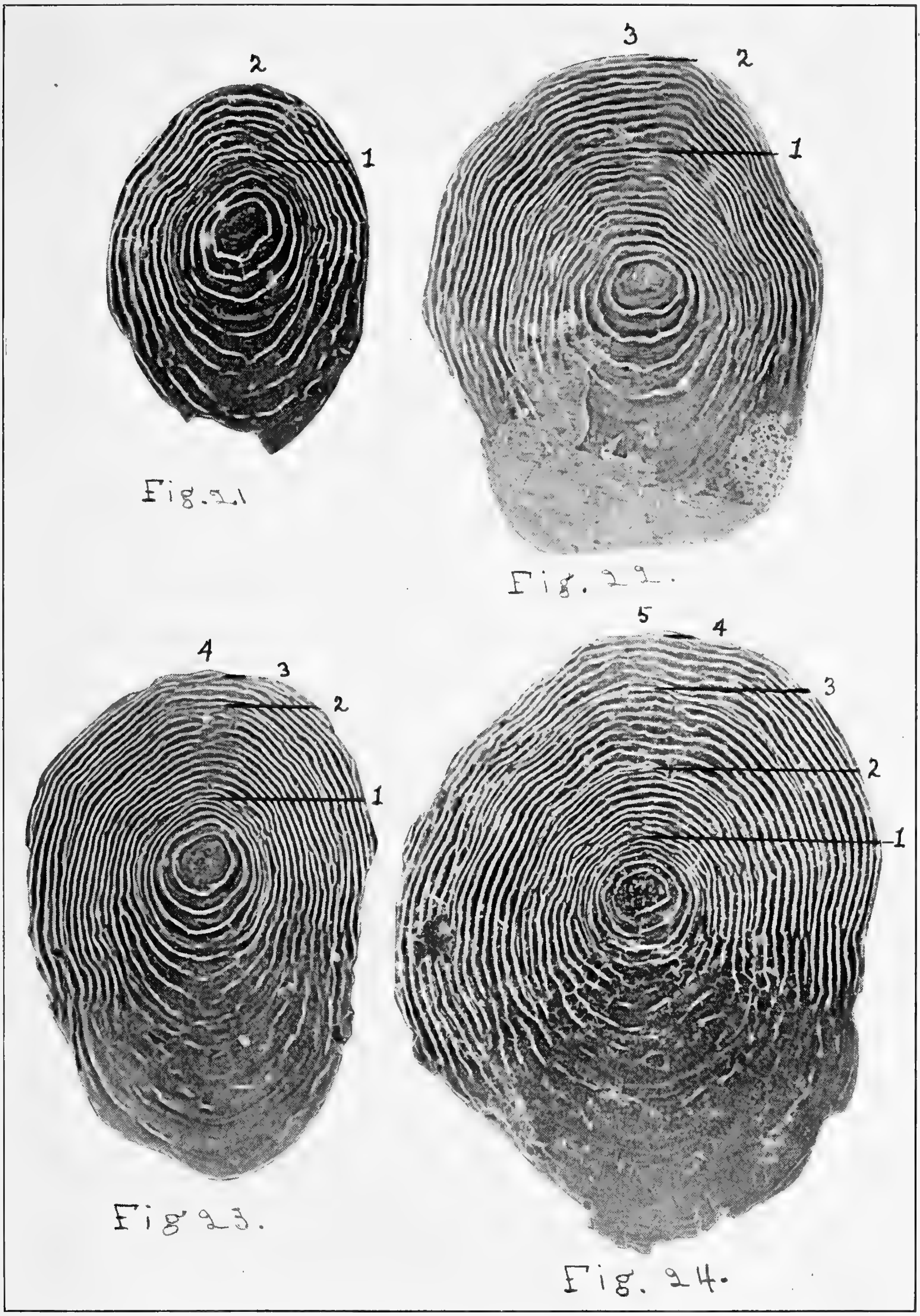
The effect of age on such precocious maturing is shown by the fact that none of the individuals that belong to the two youngest groups of seaward migrants—those in their first and those in their second years—mature thus precociously, and they do not appear in the run until their third year in the sea. It is demonstrated further by the fact that the 3-year migrants rarely mature during their first sea year. For although the 3-year migrants greatly outnumber those that seek the sea in their fourth year, the latter group produces over 90 per cent of the No. 1 grilse. It would seem that in this case age alone must be the determining factor, for although the 4-year migrants average a little larger than do those in their third year, the amount of overlap is so great as virtually to eliminate size as a factor of any considerable importance.

The two factors that by their interaction seem largely to control the phenomena of early maturing in the sea life of the fish are age and sex. The effect of the two working concurrently is shown in illuminating fashion in the history of the No. 2 grilse, which mature during their second year in the sea. Descending the river as fingerlings the previous year, they had spent the summer and winter, and more or less of the second season, feeding vigorously in the sea. A few of them appear in the early portion of the run with the first fish to enter in May, and there are some stragglers that accompany the run into late June or early July. Then comes an interval of several weeks in which no grilse appear, to be followed late in the season by a period in which they occur in much greater numbers than at any previous time. In certain seasons they constitute, numerically, a very considerable proportion (as much as 30 per cent) of the fish that form the latter part of the run. They are still obviously undersized fish, and although the larger individuals overlap in size the smallest of the next older group, the greater part of them are easily segregated by their small size and general appearance.

Two separate year classes are represented among these No. 2 grilse—those in their fourth and those in their fifth year. They were fellow migrants from lake to sea during the same spring, when one class was in its third year and the other in its fourth. They have spent the same length of time in the sea, where their principal growth has been made, and they differ but little in average size. The reaction of these two classes to the influences that cause early maturity is most instructive. In both classes the early part of the run, during spring and early summer, is composed exclusively of male fish. In the latter part of August and in September mature females appear in both classes, but in widely different proportions, the 5-year class containing a much larger relative number of females than does the 4-year group. This becomes obvious in the following table, which gives separately for 1924, 1925, and 1926 the numbers of the sexes in No. 2 grilse taken by random sampling early in September.

TABLE 4.—*Sex distribution in grilse*

Year	Four-year grilse			Five-year grilse		
	Males	Females	Per cent females	Males	Females	Per cent females
1924	325	43	12	229	174	43
1925	190	35	16	90	56	38
1926	41	7	15	92	38	29



SEAWARD MIGRANT RED-SALMON FINGERLINGS, 1926

Fig. 21.—Female in second year, 94 millimeters long, June, 10, 1926
Fig. 22.—Male in third year, 144 millimeters long, May 30, 1926
Fig. 23.—Male in fourth year, 145 millimeters long, May 30, 1926
Fig. 24.—Male in fifth year, 175 millimeters long, June 10, 1926

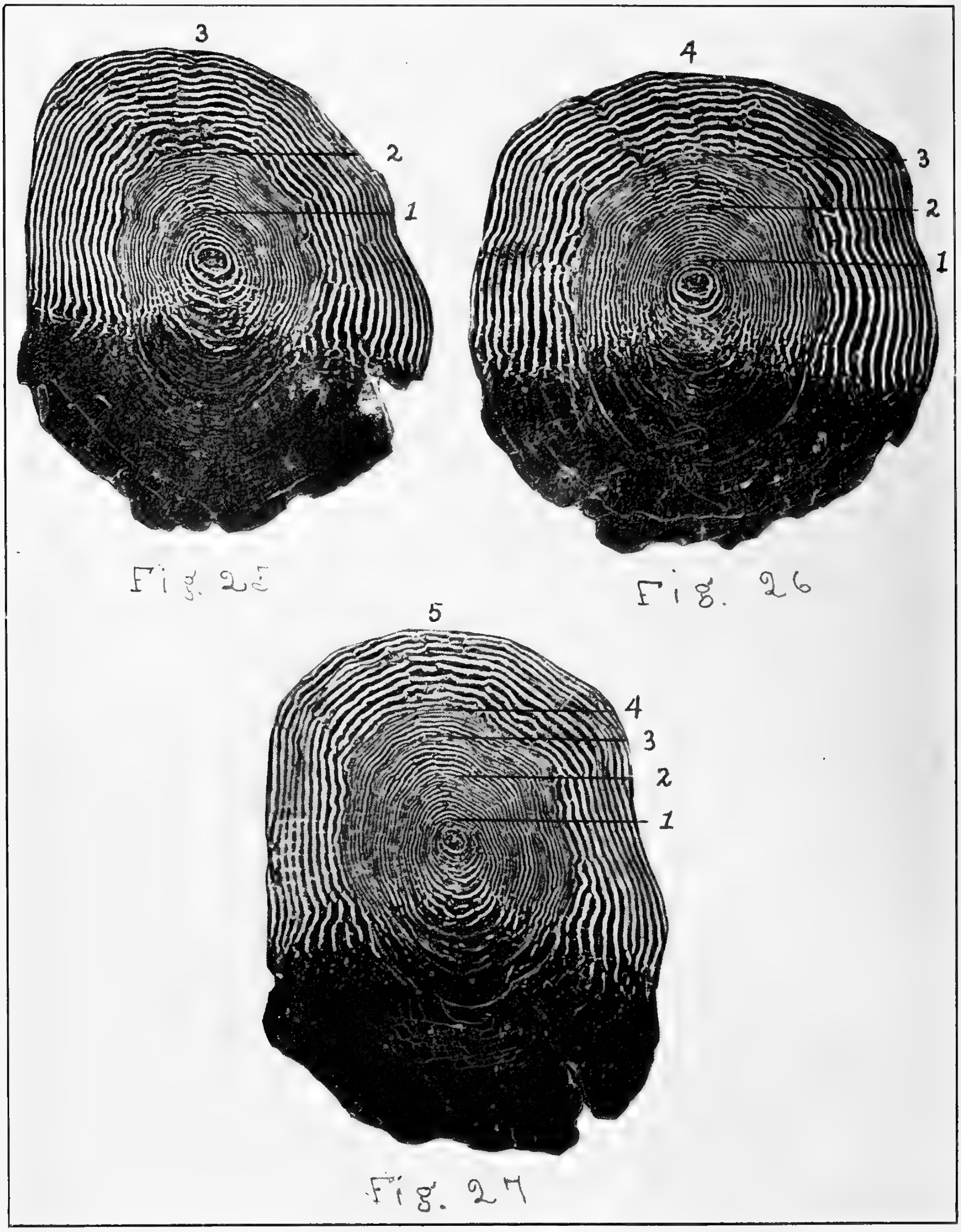


Fig. 25.—Male of 3_3 age group, 33 centimeters long, September 12, 1924
Fig. 26.—Male of 4_4 age group, 34 centimeters long, September 9, 1924
Fig. 27.—Male of 5_5 age group, 33 centimeters long, September 9, 1924

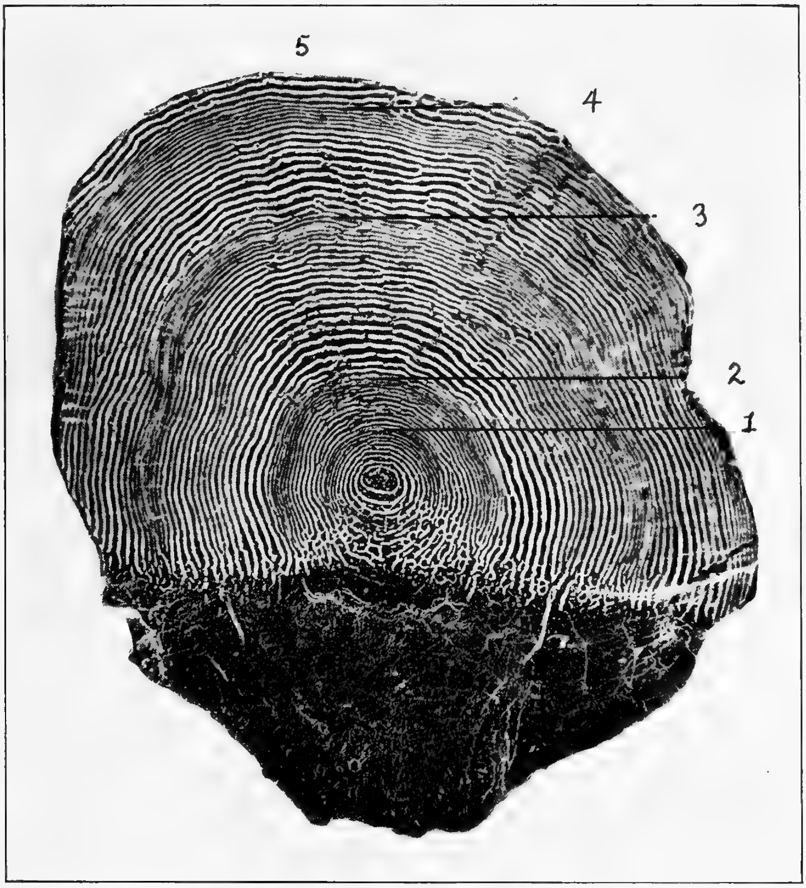


Fig. 28.—Male of 5_3 age group, 61 centimeters long, June 9, 1924

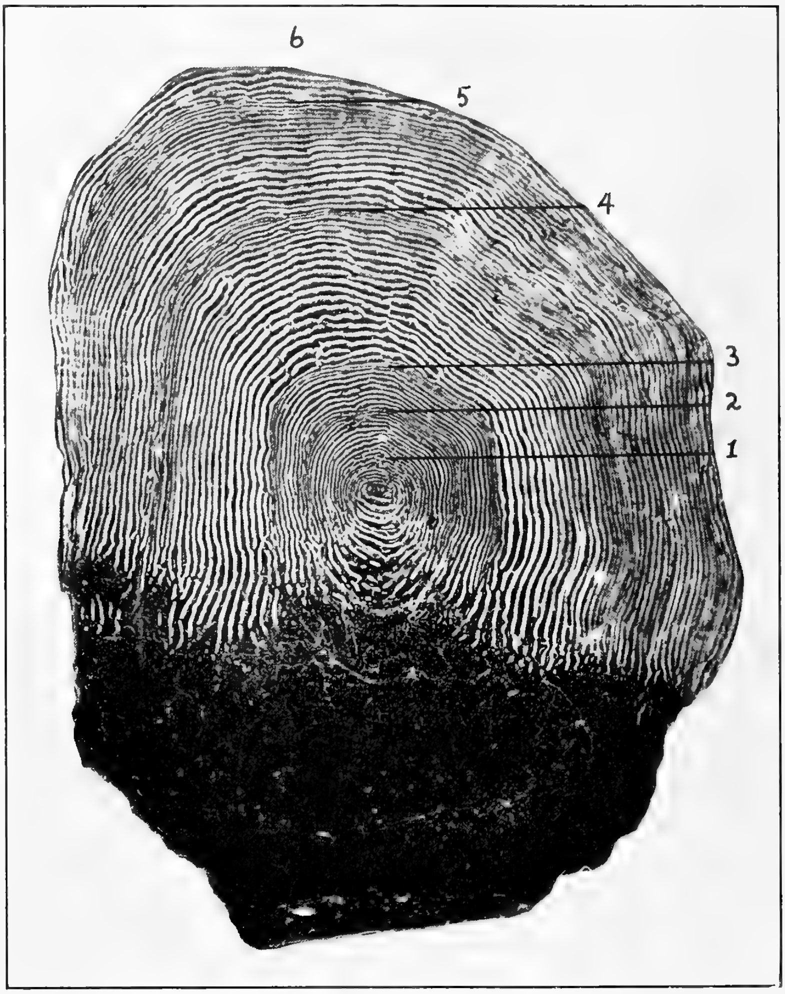


Fig. 29.—Female of 6_4 age group, 55 centimeters long, June 9, 1924

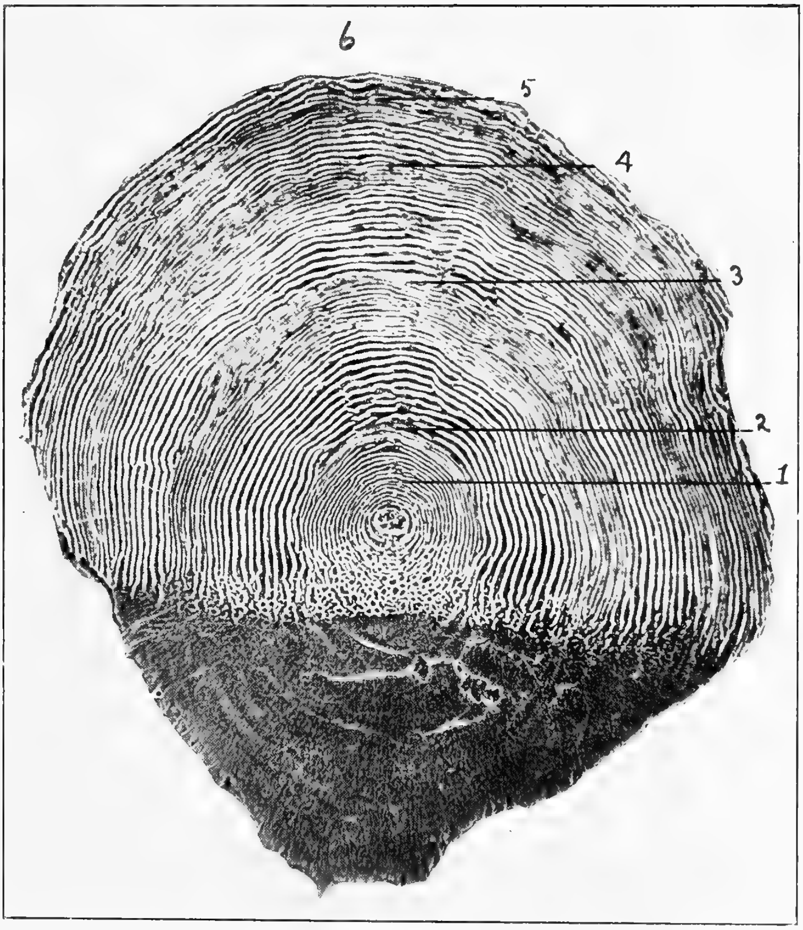


Fig. 30.—Male of 6_3 age group, 68 centimeters long, June 9, 1924

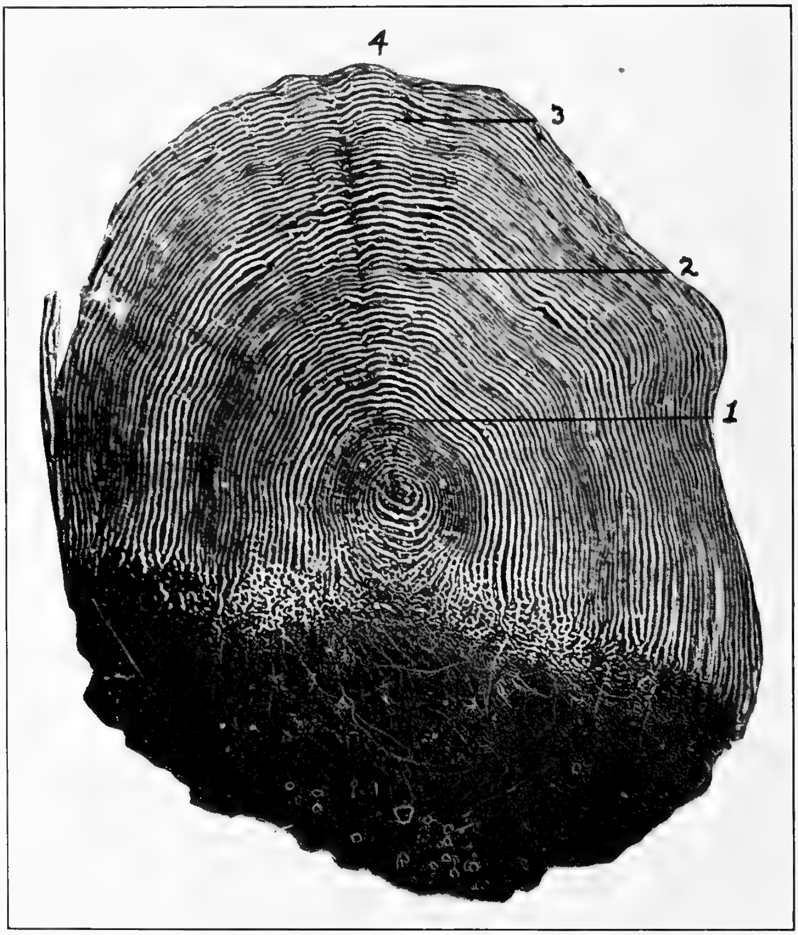


Fig. 31.—Female of 4_2 age group, 57 centimeters long, June 25, 1924

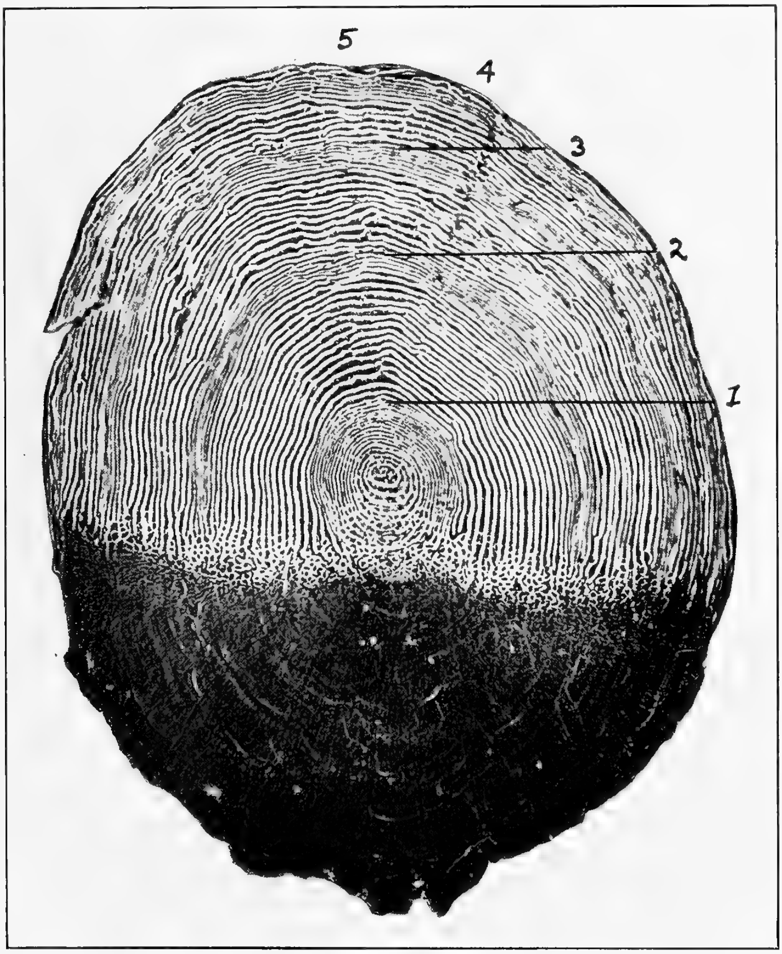


Fig. 32.—Female of 5_2 age group, 57 centimeters long, June 16, 1924

As we have previously stated, the Karluk grilse have little commercial value. Their flesh is conspicuously deficient in color and oil and their size is so small they can not be handled economically. As they are so largely males, they could have biological significance, it would seem, only in case there were a marked deficiency of males among the older fish that make up the main body of the run. A deficiency of males does exist, in fact, and this appears to be a constant feature of the Karluk race. Excluding from consideration the grilse, our random sampling of adults throughout the season of 1924 (4,776 individuals) gave 46 per cent males and 54 per cent females. In 1925, with 5,214 individuals, there were 44 per cent males and 56 per cent females. In 1926, with 8,114 individuals, there were 43 per cent males and 57 per cent females. This is an unusual condition among red-salmon races and appears the more remarkable from the fact that, aside from the grilse, every important year class shows a deficiency of males. Whether in natural spawning, with a deficiency of males, a single male will serve more than one female is a question to which we have no answer as yet. If they will not do so, the unusual development of grilse in the Karluk race may have a useful purpose.

To recapitulate: No. 1 grilse spend a single summer in sea feeding, are exclusively males, and become mature near the close of the same season in which they migrate seaward from the lake. They are drawn almost exclusively from migrating fingerlings in their fourth and fifth years. The much larger group of 3-year fingerlings contributes very few individuals that mature during their first summer in the sea.

No. 2 grilse mature during their second summer in the sea and in greatest numbers toward the close of the summer, when females appear in limited numbers with the greatly preponderating males.

The great majority of the Karluk red salmon, those that constitute the backbone of the run, mature during their third summer in the sea, when they are in their fifth or sixth year. Of these two, the 5-year class is by far the most important, for it develops from the 3-year fingerlings, which constitute the great majority of the downstream migrants. The 4-year fingerlings also develop principally during their third summer at sea and form the sixth year class above mentioned. It constitutes the second most important group in the run. In 1926, the 5-year class here considered comprised about 80 per cent of the run and the 6-year class about 10 per cent.

We can state, therefore, that despite the very wide diversity in life history found among the Karluk red salmon, there is one prevailing mode to which the majority conform. These migrate seaward as fingerlings in their third year and mature in their fifth year, during their third summer at sea. In case the fingerlings have lingered one year longer in fresh water, they still largely conform to the racial habit of maturing in their third sea summer and are then in their sixth year.

ANALYSES OF RECENT RUNS

As previously stated, the primary object of our investigation is to ascertain the natural yield from a spawning colony of known size—to determine the ratio between the number of parents spawning in any given year and the number of the resulting progeny, when the latter shall return at maturity. Will a single pair of spawners produce, on the average, 1 pair of mature salmon, or 2 pairs, or 5 pairs, or 10 pairs?

The secondary object is to conduct these investigations over a sufficient period of time that we may determine to what extent results will vary in different years, due to natural influences, favorable or unfavorable, which shift in effectiveness from year to year. This will constitute a quantitative study of fluctuations in abundance due to natural causes.

The varying productivity from year to year in a given salmon fishery is due to the interaction of the two factors that we here propose as objects of our investigation. An unusually small run of salmon in any river in a given year may be due to insufficient spawning in the corresponding year of the preceding cycle, or it may be due to unusually unfavorable conditions that have increased mortality among the members of the brood beyond the ordinary, or it may be due to a combination of the two factors. We have at present no means of making a direct study of fluctuations in abundance due to natural causes. Many of these are unknown to us, and with regard to the rest their effect can in no instance be quantitatively determined; but when we shall have eliminated from our problem variations in yield due to differing intensities of spawning, as we hope to do in the prosecution of these investigations, all fluctuations that can not be accounted for by this primary cause must be referred to the total effect of shifting natural conditions. The relative importance of the two can then be determined, and we can ascertain how high a degree of correlation exists between the intensity of spawning and the productivity of the fishery. If normally a high degree of correlation exists, the problem of an effective administration of the salmon fisheries will be greatly simplified. To produce consistently large runs, it will be necessary only to provide spawning reserves of sufficient size, which it will be within our ability to determine. If, on the other hand, it shall prove that fluctuations due to causes beyond our control are of preponderating influence and largely mask the effects of variable spawning, a successful administration of the fisheries will be rendered more difficult and uncertain. A larger safety factor would then be called for. Larger spawning reserves would have to be provided in order that their more numerous progeny can neutralize in some measure the disastrous effects of unfavorable years. It is not necessary to point out that predictions of the size of future runs, based on the size of spawning colonies year by year, will have value in such degree only as we establish correlation between numbers of spawning fish and the number of their progeny that attain maturity and enter the runs. Such predictions will be unreliable in such degree as fluctuations due to natural causes interfere with the expected results.

Our primary line of investigation calls first for an accurate determination each year of the total returns of red salmon to the Karluk River and the division of these between commercial catch and spawning escapement. The commercial catch is obtained directly from the companies that operate in the Karluk district, and the spawning escapement is obtained at a counting weir operated by the Bureau of Fisheries near the mouth of the river. Returns from these two sources are now available for each year from 1921 to 1926, inclusive.

Having, then, the complete census of each annual run, as well as the number of salmon that each year comprise the spawning reserve, it remains only to recognize and enumerate the progeny of the various spawnings as they return at maturity, in order to establish the ratio of increase for which we are seeking. This could be

done easily if all the progeny of a given spawning matured at the same age and thus constituted the run of a given year; but, as we have seen, maturity in the Karluk race is attained at any age from 3 to 8 years. The returns from the 1921 spawning, for instance, are distributed throughout the runs from 1924 to 1929, and those of 1922 from 1925 to 1930. If our aim is to be accomplished, each year's run must be analyzed into its various age components, and each of these must be determined quantitatively. By this method we can be prepared to add together the 3-year fish of 1924, the 4-year contingent of 1925, the 5-year quota of 1926, the 6-year group of 1927, the 7-year group of 1928, and the rare 8-year individuals of 1929, and obtain a total that will represent the complete returns of the 1921 spawning; and so on, by the same method, for each succeeding year.

This analysis of the runs is conducted by the customary method of random sampling. A certain number of individuals are taken at random, without selection, to form what is considered an adequate sample of the commercial catch on a given day. The sample must be large enough to furnish reliable data concerning the constitution of the run on the day on which it is taken, and successive samples must be obtained at close enough intervals to present a record of such changes in the constitution of the run as may develop from time to time throughout the season. Believing it wiser to err on the safe side of unnecessarily extensive sampling, rather than the reverse, we are attempting in each sample to secure data from 100 or more individuals taken by the random method. With regard to each individual, we obtain length, weight, sex, and a specimen of scales for the determination of age. The results have been such as to assure us of the adequacy of our method and the sufficiency of our sampling to present a reliable cross section of the entire run.

Although no returns from the 1921 spawning—the first for which we had numerical data—could be looked for until 1924, we undertook an analysis of the run of 1922, to survey the field and secure a background for the determinations of future years. The characteristics of the Karluk race were not wholly unknown to us at that time, for as a part of our general investigation of red-salmon races we had previously examined limited samples of the runs of 1916, 1917, 1919, and 1921. For each of these years, except, perhaps, 1917, the samples were too small to permit generalizations as to the characteristics of the entire run, being confined to one or two days of the season only. We have material gathered on seven different days in July and August in 1917. We include returns from each of these years for such value as they may have for purposes of comparison.

Having established our base line in 1922, our series of complete consecutive analyses begins in 1924 and should continue without interruption as long as the investigation is in progress. The results obtained are not to be confined to the segregation and enumeration of age groups, although this is our prime object. Many other important facts in the life history of the Karluk salmon will emerge, it is hoped, from the data obtained. These should include, among others, unexplored phenomena in the growth of the salmon and in the quantitative relations of the various age groups that develop in the broods of successive years. The latter is a most important subject, from the practical standpoint, and is one concerning which no information has been obtainable hitherto. In the line of our present experiment, we shall ascertain the numbers of each age group that develop from the eggs of a given brood and,

accordingly, the proportions in which each age group is present among the progeny of a certain spawning. By comparison of similar figures from successive spawnings, we shall be prepared to develop the amount of variation that is found in this relation. If, for instance, among the progeny of the 1921 spawning we find that the 6-year age group comprises 20 per cent of the whole, how will this compare with the 6-year group that develops from the 1922 spawning, and this with the results of successive years? Will they also be present in approximately 20 per cent of the whole, or will the relation be a widely varying one in successive broods? If in the relative numbers of each age group a fair degree of uniformity is found to develop from different lots of eggs, the number of individuals found in the younger age groups of any brood, which are the first to make their appearance in the runs, will serve as a reliable basis for prophecy concerning the size of successive age groups that develop from this same lot of eggs. From the size of these early samples of the brood we should be able to compute with a fair approach to accuracy the sum total of all the progeny of this spawning and would find ourselves in possession of that great desideratum—a reliable basis for prophecy concerning the size of future runs. If, however, the relative number in various broods that develop at the same age is highly variable, the size of the younger age groups, as they successively appear, would present but indifferent evidence concerning the size of the older age groups, some of which may well constitute the dominant group or groups in future runs. If such wide variation exists, we can only seek for causative factors and may succeed in correlating a tendency in a certain brood toward early or late maturing with a certain set of external conditions.

For convenience of reference in connection with the following discussion of dominant and other age groups and the brood years to which they are referred, we present below the records of Karluk red-salmon packs, in even thousands of cases (48 one-pound cans to the case), from 1910 to 1920. We have no evidence concerning the size of the spawning escapements for these years.

We present below our analyses of the runs of the various years for which we have data, taking them in chronological order.

	Cases		Cases
1910	107, 000	1916	167, 000
1911	124, 000	1917	166, 000
1912	89, 000	1918	78, 000
1913	62, 000	1919	78, 000
1914	39, 000	1920	98, 000
1915	59, 000		

RUNS OF 1916 AND 1917

For a period of four years immediately preceding 1916 the Karluk pack of red salmon had been very poor, ranging from 39,000 cases in 1914 to 89,000 cases in 1912. In 1916 and 1917, however, the pack suddenly increased to over 165,000 cases in each of those years. It becomes of interest to ascertain the prevailing age of the 1916 and 1917 fish and to discover which brood years had been mainly responsible for the sudden increase in the runs of those two years.

Our samples of the 1916 fish are but two in number—one of 116 fish taken on July 19, the other of 266 fish obtained August 24. An analysis of these is given in

Table 5, from which it appears that the predominating age group is the 5_3's—fish that migrated seaward as fingerlings in their third year and matured and entered the run in their fifth year. Eighty-five per cent of our material belongs to this group and must therefore have developed from eggs laid down in 1911, when the Karluk red-salmon pack amounted to 124,000 cases. The only other age groups represented in significant numbers are the 6_3's and 6_4's, and as both of these matured in their sixth year, they developed from the brood year 1910. Together, they comprise 13 per cent of the samples obtained, a not unusual proportion of 6-year fish in runs of other years. The pack of red salmon in 1910 amounted to 107,000 cases, and while the 6-year progeny of that year appear in normal numbers in the run of 1916, the 5-year group, which probably was largely responsible for the run of 1915, was very limited, if we judge from the 1915 pack, which was of only 59,000 cases.

Table 5.—*Random samples of the Karluk red-salmon run of 1916, distributed by age groups, sex, and length*

[M=male; F=female]

Length in inches	Age group and sex											Total
	4_2	4_3		5_3		5_4		6_3		6_4		
	F	M	F	M	F	M	F	M	F	M	F	
18												
18½			1				1					
19												
19½		1										
20	1											
20½												
21					4							
21½				1	5	1	1					
22					19							
22½				1	27						3	
23				7	41	1		1	1		10	
23½				8	39					2	3	
24				20	45				1	5	4	
24½				19	14					3	2	
25				29	6			1	1	6		
25½				25	1			1	3	1		
26				9					1			
26½				4				1				
27				1								
Total	1	1	1	124	201	2	2	4	7	17	22	382

The 1917 run is represented in our material by the following samples:

	Individuals
July 10	249
Aug. 18	100
Aug. 23	99
Aug. 25	210
Aug. 26	100
Total	758

As indicated in Table 6, the proportions of the principal age groups in 1917 are very similar to those obtaining in our samples for 1916. The 5_3 group is again dominant and comprises 88 per cent of the whole, while the two 6-year groups (6_3 and 6_4) together amount to 10.4 per cent. An unusually large proportion of the 1917 run is thus seen to be derived from the spawning of 1912, a year in which the commercial take was rather poor (89,000 cases). Whether the spawning escapement

of that year was disproportionately heavy, as compared with the commercial catch, or whether the natural conditions were unusually favorable for the 1912 brood, with the mortality factor greatly reduced, is a question concerning which we have no information for this year. Whether such lack of correlation as frequently exists between commerical catches of the corresponding years of successive cycles is due to discrepancies between the commercial catches and the spawning escapements, or to the disturbing influence of the variable natural factors (aside from spawning intensity) that control abundance, is the principal problem we hope to solve by means of the present series of experiments.

TABLE 6.—*Random samples of the Karluk red-salmon run of 1917, distributed by age groups, sex, and length*

[M=male; F=female]

Length, in inches	Age groups and sex																	Total
	3_1		3_2	4_1		4_2		5_2		5_3		5_4	6_3		6_4		7_4	
	M	F	M	M	F	M	F	M	F	M	F	M	M	F	M	F	M	
16			1															
19												1						
19½																		
20																		
20½											1							
21											2							
21½										2	2					1		
22										3	9	1				1		
22½										3	11					2		
23	1	1		1			1		1	17	38		1	1		4		
23½					1					16	51			1		3		
24						1			1	26	69			7	3	7		
24½								1	1	32	64			4	3	6		
25				1						58	63			6	4	6		
25½								1		54	15		5	2	12	4		
26								1		57	4		3	4	10	1		
26½										21			2		3			
27										8			2		2		1	
27½								1		2			2					
Total	1	1	1	2	1	1	1	4	3	299	329	2	15	25	37	35	1	758

RUNS OF 1919 AND 1921

For the year 1919 we have but a single sample, obtained on July 26 and consisting of 103 individuals. This doubtless gives reliable indication of the constitution of the run on that date but takes no account of the changing elements of the run as these appear during the course of the season. In Table 7 we enumerate the individuals in our sample and refer them to their appropriate age groups, sex, and length groupings. From this it appears that the 5_3 group continues to be dominant, constituting 81 per cent of the sample, but represents a somewhat smaller proportion of the run than in any other year we have considered. The pack of red salmon in 1919 was small, amounting to only 78,000 cases, and it is of interest to ascertain that the principal element present in the run was derived from the year 1914, which furnished the smallest pack known in the history of the river (39,000 cases).

TABLE 7.—*Random samples of the Karluk red-salmon run of 1919, distributed by age groups, sex, and length*

Length, in inches	Age groups and sex										Total
	4_2	4_3	5_2		5_3		6_3		6_4		
	M	M	M	F	M	F	M	F	M	F	
21	1										
21½		1				1					
22		1				3					
22½						2					
23						10				3	
23½					2	7					
24					2	11				1	
24½					6	8		2			
25					7	2		3			
25½					7	2		1	1		
26				1	7			1	1		
26½					5						
27					1		1				
27½					1						
28											
28½			1								
Total	1	2	1	1	38	46	1	7	2	4	103

The run of 1921 was more generous than those that immediately preceded it, being responsible for a pack of 119,000 cases, or approximately 1,670,000 fish. For the first time in that year we are in a position to state the size of the spawning escapement, which closely approximated the number of fish that entered the commercial catch. The total run to the river in that year, then, amounted to somewhat more than 3,000,000 salmon. Our samples are again very limited, consisting of two lots, the first taken on August 7, consisting of 106 individuals, and the second obtained August 16, with 105 specimens. In Table 8 we group these according to age, sex, length, and the length of residence in fresh water. Not only are the 5_3's again dominant, but they are present in larger proportion than in any other run thus far reported. Eighty-eight per cent of the samples are of this group and are derived from the brood year 1916, which was signalized by a pack of over 167,000 cases. No 4-year fish were present in our samples, although the year from which they would have been derived (1917) produced a pack almost as large as that of 1916. It is to be noted, however, that 1917 gave no indication, in any subsequent year, of having been a successful brood year. There can be no reasonable doubt that the great majority of its progeny would return to the river in 1922 as 5-year fish, but the pack of that year was only 46,000 cases.

TABLE 8.—*Random samples of the Karluk red-salmon run of 1921, distributed by age groups, sex, and length*

[M=male; F=female]

Length, in inches	Age groups and sex									Total
	5_2		5_3		6_3		6_4		7_4	
	M	F	M	F	M	F	M	F	F	
21				1						
21½			1							
22				5						
22½				6						
23			2	25				1		
23½			5	19		1	1	2		
24			8	20		2	2	1		
24½			9	14	1			1		
25	1	1	12	9	2	1	1		1	
25½			15	3	1					
26			17	2	3					
26½			2				1			
27			8				1			
27½			2							
28			1							
Total	1	1	82	104	7	4	6	5	1	211

KARLUK RED-SALMON RUN OF 1922

During the season of 1922 for the first time a fairly satisfactory series of samplings was attempted, although these were smaller and less frequent than in subsequent years. Two samplings per week were planned, of 75 individuals each, the first taken June 5 and the last September 18. There were 33 samples in all, evenly distributed, 3 or 4 days apart, between the above-mentioned dates. The tota number of individuals examined and included in this report is 2,469.

The year 1922 offers one of the conspicuous failures in correlation between the packs of a brood year and the year in which the progeny of the brood year largely return. As we have already seen, the Karluk red salmon mature principally at the age of 5 years, and the race has established, therefore, a well-marked 5-year cycle. The only other age that participates to any considerable degree in the run is six, the five and six year fish together constituting usually over 95 per cent of the run. This being the case, the brood years for the 1922 run were 1916 and 1917, in each of which over 165,000 cases of red salmon were packed. Using size of pack as a basis for prediction, it would have seemed highly probable that the year 1922 would produce one of the largest packs of recent years, for it could be expected to include the 5-year fish from 1917 and the 6-year fish from 1916—two outstanding years, each of which had produced a pack larger than that of any of the intervening years between 1916 and 1907. The results in 1922, however, were not at all in accord with such a prophecy, for the red-salmon pack of that year amounted only to 46,000 cases.

The analysis of our samplings of the run, presented in Table 9, shows beyond question that the failure in this instance was caused by the very meager returns from the brood year 1917. Not only was the total pack of 1922 very small, but the proportion of this poor pack produced by the progeny of 1917 was extrordinarily low, consisting of only 63 per cent, whereas in normal years the 5-year fish comprise 80 per cent or more of the total run. If it had not been for the unusually large proportional contribution to the run made by the other brood year (1916), the results would have been even more serious. For, whereas the 6-year fish in normal years make only 10 to 15 per cent of the run, in 1922 these constituted 36 per cent. From

these facts it is apparent that the year 1916 produced a normal brood and contributed its due quota to the run of 1922, while the year 1917, with a pack practically equal to 1916, had been largely a failure. The cause of this failure is again beyond our knowledge. Weather conditions may have favored more than usually intensive fishing, and the commercial catch may have been large at the expense of the spawning escapement. In that case, the pack of 166,000 cases in 1917 may have included the greater part of the run of that year, with the escapement so reduced below a safe minimum that no favorable results were possible. The only other alternative would be a spawning escapement perhaps equally as large as was that of 1916, the disparity in the results of the two years being due to unfavorable natural conditions that decimated the 1917 brood. This question has always recurred in every discussion of brood years and the runs for which they are responsible, and has always been left without answer. Only when we shall deal with years in which the size of spawning escapement is known, can we hope for a solution.

TABLE 9.—*Random samplings of the Karluk red-salmon run of 1922, distributed by age groups, sex, and length*

Length, in centimeters	Age groups and sex																				Total
	4_1	4_2		4_3		4_4	5_2		5_3		5_4		5_5	6_3		6_4		6_5	7_4		
	M	M	F	M	F	M	M	F	M	F	M	F	M	M	F	M	F	M	M	F	
30						1															1
31						1															1
32																					
33						1															1
34													1								1
35																					
36																					
37																					
38																					
39																					
40				1																	1
41											1										1
42																					
43									1												1
44											1										1
45				2							1										3
46				1																	1
47			1							1	1										3
48										4		2									6
49			1						3	8	1										13
50				4					3	7	4					1	2				21
51				1					3	14	1				2	2	1				24
52			1	1					5	22	2	1		2	2	1	1				38
53				1	1				17	31	4			2	7		3	1			67
54			1	1				1	25	48	1			4	13	3	3			1	101
55		1		3				2	35	33	1			6	19	3	3		1		107
56		1		1					30	50	1	1		10	27		5				126
57				1	1		1		37	49	2			4	37	5	2				139
58			3						50	80	1			18	43	6	7				208
59			1						62	105				18	63	2	6				257
60								2	51	82	1			27	68	6	7				244
61									48	89				31	62	9	9				248
62		1	4				1		70	70				32	42	9	4			1	234
63			1				1		72	46				35	24	11	5				195
64	3								72	23				31	10	5					144
65									46	11				37	6	8	1			1	110
66							1		43	5				20	2	4					75
67									28	2				13	1	2					46
68									17					7		1					25
69									9					7		1					17
70									4					5							9
Total	3	3	13	17	2	3	4	5	731	780	23	4	1	309	428	79	59	1	1	3	2,469

The frequency of sampling necessary to give an adequate account of the constitution of the run during the entire season depends, of course, on the degree of uniformity or the lack of uniformity in the run itself from day to day and from week to week. As appears in Table 10, which follows, 12 different age groups were represented in the

run of 1922, three of which (5_3, 6_3, and 6_4) comprised nearly 97 per cent of the run. Had these been present in fairly uniform relative abundance throughout the season, very few samplings would have answered our purpose; but such was by no means the case. The two major groups, especially (5_3 and 6_3), varied widely in this respect, the 5_3 group being present in largest relative numbers during the latter portion of the season, when the 6_3's were least abundant, the two varying fairly uniformly in opposite directions, until in August and September the 6_3's had almost disppeared from the run. In Table 10, we give, for each of the days throughout the season in which samples were taken, the percentage in which each age group was present. The marked trend toward increasing percentages in the 5_3's and diminishing percentages in the 6_3's as the season advances is clearly apparent. A similar phenomenon is also obvious in other age groups. In the next most important group, the 6_4's, there is a less marked but still evident tendency in the same direction as in the 5_3's toward relative increase in the latter part of the season. This is also unmistakable in the groups 4_2, 4_3, 4_4, 5_4, and 5_5, while in 4_1 and 5_2 the reverse again is the case, these two groups agreeing with 6_3 in running predominantly or altogether in the early part of the run. The constitution of the run is therefore a constantly changing one, with certain groups increasing as the season progresses or making their appearance only toward its latter end, while other groups are either confined to the first few weeks or appear in largest relative numbers at that time.

The early running groups (4_1, 5_2, and 6_3), we note with interest, differ widely in age but agree in the length of time they spent in the sea, which is one year in excess of the period spent by the late-running groups above enumerated. A comparison with similar data for subsequent years will be of value.

TABLE 10.—*Percentage of all classes, Karluk run of 1922, in random samplings taken on a series of dates*

Date	4_1	4_2	4_3	4_4	5_2	5_3	5_4	5_5	6_3	6_4	6_5	7_4
June 5	1.5				1.5	31			66			
June 7					1	31			68			
June 10					1	28			68	3		
June 13	1	1			3	42			53			
June 16	1					28	1		69	1		
June 19		1			1	46	1		48	3		
June 22						28	1		66	5		
June 24			4		1	36	1		57	1		
June 27			3		3	33			58	3		
July 1						37			56	7		
July 5		1				38	1		56	4		
July 8						36	5		48	11		
July 12						36			55	9		
July 14						59	1		27	13		
July 17		1	1			66			27	4		1
July 20		1				68			26	4		1
July 24						84	1		11	4		
July 27						72			20	8		
July 31						67			23	8	1	1
Aug. 3						73			19	8		
Aug. 7		1	3			71			15	9		1
Aug. 10			1			81			15	3		
Aug. 14		1				94	1		3	1		
Aug. 17		1				84	1		7	7		
Aug. 21		1				87			7	5		
Aug. 24		1				83	1		3	12		
Aug. 28		1	1			72	3		3	20		
Aug. 31		1				75	4		1	19		
Sept. 4			1	1		86	3		3	4		
Sept. 8			4			89	3		1	3		
Sept. 11		1	1			94	1		1	2		
Sept. 14		1	3	3		87		1	1	4		
Sept. 18		3	3			89	4		1			

Another series of changes that progressively follow the course of the run are the increases in length and weight in both sexes of all the age groups. As an example of the increase in length, we give in Table 11 the average lengths, in centimeters, for males and females of the 5_3 group, separately for each date on which samples were taken, the series being smoothed twice by threes.

It will be apparent from this series that while the upward trend in length is unmistakable for the entire season, it does not progress uniformly. In fact, throughout the month of June the lengths in both males and females decrease fairly uniformly with each succeeding sample, the increase beginning with the sample of July 1 in the males and in the sample of June 27 in the case of females. This increase is of short duration, however, for on July 14, in both males and females, another decrease sets in, which reaches its culmination in both sexes on July 20. A more rapid increase is then registered, which continues without interruption to the close of the season in the case of males, with a slight recession in the mid-September samples in the females.

Other age groups give evidence of similar increase in size during the season, but the number of individuals present in each sample is so small that a reliable series of averages can not be secured.

TABLE 11.—*Karluk red-salmon run, 1922*

[Average lengths, in centimeters, of age group 5_3 on a series of dates]

Date	Males	Females	Date	Males	Females	Date	Males	Females
June 5	58.8	57.0	July 12	58.9	56.8	Aug. 21	63.6	60.7
June 7	58.6	56.9	July 14	58.5	56.0	Aug. 24	63.8	60.7
June 10	58.5	56.5	July 17	57.3	54.6	Aug. 28	63.8	60.7
June 13	58.3	56.2	July 20	56.6	53.5	Aug. 31	63.9	60.8
June 16	57.8	55.9	July 24	57.0	53.7	Sept. 4	64.1	60.9
June 19	57.6	55.5	July 27	58.5	55.2	Sept. 8	64.1	60.9
June 22	57.5	55.4	July 31	60.4	57.3	Sept. 11	64.1	60.8
June 24	57.2	55.3	Aug. 3	61.5	58.7	Sept. 14	64.3	60.5
June 27	56.8	55.4	Aug. 7	62.1	59.4	Sept. 18	64.3	60.3
July 1	57.1	55.5	Aug. 10	62.3	59.8			
July 5	57.7	56.0	Aug. 14	62.7	60.3	Mean	60.3	57.7
July 8	58.7	56.6	Aug. 17	63.2	59.8			

KARLUK RED-SALMON RUN OF 1924

The two years mainly responsible for the run of 1924 were 1918 and 1919, each of which had furnished a small or moderate pack of approximately 78,000 cases. The 5-year and 6-year fish derived from these two brood years were in normal relative numbers, the 5-year fish constituting 79 per cent of the run, the 6-year fish 17 per cent. The remaining 4 per cent were largely 4-year fish of the 4_3 group. These were grilse, largely males, which migrated seaward as fingerlings in the spring of 1923 and matured precociously as undersized fish of little value.

The random sampling of this year was on a larger scale than heretofore, material being obtained whenever possible on each day during the fishing season. The total number of individuals thus obtained was 5,132, and these are distributed by age group, sex, and length in Table 12, which follows. The age groups represented in the run are essentially the same as those that appeared in 1922. A single group, 3_3, lacking in 1922, was represented in our 1924 samplings by a single specimen; while two groups, 5_5 and 6_5, each represented by a single individual in our 1922 material, were not present in 1924. The groups 5_3, 6_3, and 6_4 again exceeded in numbers any of the other groups present, and together constituted 92 per cent of the run.

TABLE 12.—*Random samplings of the Karluk red-salmon run of 1924, distributed by age groups, sex, and length*

Length, in centimeters	Age groups and sex																			Total
	3_3	4_1	4_2		4_3		4_4	5_2		5_3		5_4		6_3		6_4		7_4		
	M	M	M	F	M	F	M	M	F	M	F	M	F	M	F	M	F	M	F	
30	1						2													3
31							2													2
32							8													8
33							1													1
34							5													5
35																				
36																				
37																				
38					2															2
39					5															5
40					4															4
41					3							1								4
42					4							1								5
43					6	1						2								9
44					6															6
45					4							3								7
46					7						1	3								11
47					5					1	6	2								14
48					7	1					3	2					1			14
49			1		10	1				3	1	1		1		2	1			21
50				1	8	2					3		1			1	1			17
51				1	13	2				4	7	6	5			1				39
52					14					3	20	5	6				4			52
53					16					10	29	12	5							72
54				3	19					19	54	11	13			2	7			128
55					12	1				29	76	13	13		1		7			152
56				1	8			1	1	36	119	19	7	1			11			204
57			1	1					2	53	193	18	2		1	6	16			293
58				2					1	69	236	13	2		7	7	29			366
59			1	2					1	83	277	6		1	9	13	43		2	438
60				1					1	107	259	2		5	24	11	54			464
61								1	1	141	267			6	17	14	57		4	508
62			1							189	220			11	22	28	51			522
63								1	1	208	146	2		11	18	39	32			458
64				1				1	2	254	78			9	11	53	19	2	2	432
65								1		194	38			18	8	45	12	2		318
66									1	172	15			10	3	38	5	1	1	246
67								1		120	1			8		31		2		163
68										55	1			7		11		1		75
69										31	1			6		3	1	1		43
70		1								8	1			1		3				14
71										3				1		1				5
72								1		1										2
Total	1	1	4	13	153	8	18	7	11	1,793	2,052	122	54	96	121	309	351	9	9	5,132
Average length	30.0	70.0	56.75	56.5	49.5	49.6	32.3	64.0	60.5	62.7	59.1	54.2	54.1	64.4	61.5	63.7	60.3	66.1	61.8	

In Table 13 we give the percentages of each age group in the series of random samplings throughout the season. The results are very similar to those we obtained in the run of 1922. Certain groups are most abundantly represented in the early part of the run or are entirely confined to it, while other groups are the reverse of this and either grow more numerous in the latter part of the run or else are found in this part only. In our discussion of the run of 1922, we stated that the data we had for that year indicated that the early running groups had spent the longest time in the sea before maturing, while the groups that showed a distinct tendency to mature and enter the run in the latter part of the season were those whose sojourn in the sea had been of shorter duration. We will now pass the different groups of the 1924 run in review to ascertain what degree of correspondence is found in the two years.

The two groups that spent the least time in the sea are the 3_3 and the 4_4 groups. Each of these matured and entered the run during the same season in which it descended to the sea as a fingerling. As shown in Table 13, the few individuals of

these groups that we secured in our random sampling were taken only in the latter part of the summer.

Those next in succession are the 4_3 and the 5_4 groups, which matured during their second season in the sea, remaining one year longer than the 3_3 and the 4_4 groups. In the 4_3 and 5_4 groups an interesting anomaly is found in the presence of two distinct maxima in their runs. As shown in Table 13, a portion of them enter early with the first part of the run, are found each day consistently in our samples, and then, for a period of a month or more, almost wholly disappear, to be followed in August and September with a second run of greater proportions than the first. The early running fish of these two groups agree in being exclusively males, while in the fall a sprinkling of females appear, the majority of which belong to the 5_4 group. We have no explanation to offer for this peculiar feature of their run. In Table 10, for the year 1922, the same bimodal tendency is shown in these two groups; less marked than in 1924, because the representatives of the groups in 1922 were comparatively few in number.

TABLE 13.—*Karluk red-salmon run of 1924. Percentages of each age group in random samplings throughout season*

Date	3_3	4_1	4_2	4_3	4_4	5_2	5_3	5_4	6_3	6_4	7_4
June 9 and 10				5		1	72		18	2	2
June 11 and 12			1	2		1	83	1	8	3	1
June 13 and 14				1		1	81		10	7	
June 16 and 17			1	2		2	78	1	10	6	
June 18 and 19			1	2			84	1	4	8	
June 20 and 21				2		1	82	2	4	8	1
June 23				1			86	1	4	7	1
June 25 and 26			1	2			80	1	10	5	1
June 27				4		1	84		6	5	
June 30 to July 1				4		1	80	1	6	8	
July 3				6		1	72	2	7	11	1
July 6			1	2		1	72	2	7	15	
July 7						3	72		11	13	1
July 8 and 9		1				1	81		2	15	
July 10 and 11						1	76		4	19	
July 12 and 14			2			1	72		8	17	
July 15 and 16							73		3	22	2
July 19 and 20							69		4	24	3
July 22 and 23			2	1			66		8	23	
July 24 and 25							80		4	15	1
July 26 and 28							79	1	2	18	
July 29 and 30							75		5	20	
July 31 and Aug. 1			1	1			81		2	14	1
Aug. 2 and 4				2			72		5	21	
Aug. 5 and 6				3			75		2	20	
Aug. 7 and 8						1	61	1	2	35	
Aug. 9 and 16				1			81		1	17	
Aug. 18 and 19				4			79	3		14	
Aug. 20 and 21			1	5			69	7		18	
Aug. 22 and 23				3			79	5		13	
Aug. 25 and 26				3			81	1		15	
Aug. 27 and 28				2	1		76	2	2	17	
Aug. 30 and Sept. 1	1			4	2		73	6		14	
Sept. 2 and 4				15			64	23		9	
Sept. 6 and 8				3			73	9		15	
Sept. 9 and 10				9	8		61	12		10	
Sept. 11 and 12				7			71	13		9	
Sept. 13 and 15				8	2		59	18	1	12	
Sept. 16 and 18				10	3		68	8	1	10	

The next series, selected on the basis of length of residence in the sea, are the 4_2, 5_3, and 6_4 groups. In each of these maturity was reached in their third season in the sea. In a measure they seem to present a transition between the early-running and late-running series. In 1922 the 4_2 group appeared to belong with the latter, as the majority of the individuals occurred in the samples taken in August and September; but in the 1924 run no such tendency is shown, as virtually all the samples ob-

tained were taken in June and July. This group is sparsely represented in the run at all times, and an examination of its participation in future runs will be necessary to decide whether it shows any distinct tendency to appear in one part of the run rather than in another. At first sight, a discrepancy seems to exist also with the 5_3 group, as between 1922 and 1924; for in 1922 the relative numbers of this group entering the daily run were lowest early in the season and increased with fair regularity until August and September. Nothing of this appears in the run of 1924. On the contrary the list of percentages shows a slight but unmistakable decrease throughout the season, the change being of such small magnitude as to suggest a balanced run in the 5_3 group, the decreasing percentages being occasioned by the increase in the 6_4 group, which is marked and fairly uniform throughout the season. In 1922 the 6_4 group was present in very small numbers and had no appreciable effect on the percentages of 5_3's, although the same tendency existed toward heavier representation in the latter part of the season; but in that year the 6_3's were present in larger numbers than in any other year within our knowledge. During the whole month of June and the first week of July this group comprised more than half of the run, and then rapidly dwindled, until in August and September it had almost disappeared. It is doubtless the association of a reduced number of the 5_3 group with an unusually strong representation of 6_3's that gives the former an appearance during 1922 of being a late-running group. In 1924 the 6_3 group was sparsely represented, being far less numerous than the 6_4's. The latter show a distinct tendency to run strongest late in the season.

The fourth series, which matured during its fourth season of sea feeding, includes the 4_1, 5_2, 6_3, and 7_4 groups. All of these show, in the 1924 run, an unmistakable tendency to strong representation early in the run. In fact, three of these groups were wholly confined to the first half of the season.

The increase in size throughout the season is as well marked in 1924 as in 1922, as is shown by comparison of Table 11 with Table 14, these giving the average lengths of the representatives of age group 5_3 in all samples taken in their respective seasons. Certain differences between the two seasons are at once apparent, the most conspicuous being the larger sizes throughout the season in 1924, as well marked in the females as in the males. The mean length, obtained from the daily averages of males in 1922, is 60.3 centimeters, while in 1924 the mean length of the males is 63.1 centimeters. The mean length of the females, obtained in the same manner, is 57.7 centimeters for 1922 and 59.6 for 1924. These differences are apparent at the beginning of the two seasons and are maintained throughout.

In addition to the greater average lengths observed in 1924, there is a certain difference in the sequences, passing down the series of lengths. In 1924 the increase in both males and females is more regular, with no periods of recession, as seen in 1922. A slight increase is apparent during June in both males and females, while in 1922 a well-marked decrease in both sexes was evident. There are other irregularities present in 1922, also, which are not registered in 1924. Due to these, perhaps, the mean length was not reached in 1922 until the first of August, while in 1924 it appeared in both sexes on July 22 and 23.

In Table 14 the series of lengths have been smoothed twice by threes.

Table 14.—*Karluk red-salmon run of 1924*

[Average lengths, in centimeters, of age group 5_3 on a series of dates]

Date	Males	Females	Date	Males	Females
June 9 and 10	60.0	57.2	July 29 and 30	63.5	59.5
June 11 and 12	59.9	57.1	July 31 to Aug. 1	63.6	59.6
June 13 and 14	60.0	57.3	Aug. 2 and 4	63.6	59.6
June 16 and 17	60.1	57.6	Aug. 5 and 6	63.6	59.6
June 18 and 19	60.3	57.8	Aug. 7 and 8	63.8	60.0
June 20 and 21	60.5	57.7	Aug. 9 and 16	64.1	60.8
June 23	60.6	57.7	Aug. 18 and 19	64.7	61.5
June 25 and 26	60.5	57.6	Aug. 20 and 21	65.0	61.8
June 27	60.2	57.5	Aug. 22 and 23	65.1	61.9
June 30 to July 1	60.3	57.5	Aug. 25 and 26	65.1	61.9
July 3	60.9	57.6	Aug. 27 and 28	65.1	61.7
July 5	61.6	57.8	Aug. 30 to Sept. 1	65.2	61.4
July 7	62.4	58.2	Sept. 2 and 4	65.3	61.2
July 8 and 9	62.6	58.6	Sept. 6 and 8	65.5	61.5
July 10 and 11	63.0	59.0	Sept. 9 and 10	65.7	62.0
July 12 and 14	63.2	59.3	Sept. 11 and 12	65.9	62.1
July 15 and 16	63.6	59.7	Sept. 13 and 15	65.7	61.8
July 17 and 18	63.5	59.9	Sept. 16 and 18	65.4	61.0
July 19 and 20	63.3	59.9	Sept. 22	65.1	61.1
July 22 and 23	63.1	59.6			
July 24 and 25	63.1	59.5	Mean	63.1	59.6
July 26 and 28	63.3	59.4			

KARLUK RED-SALMON RUN OF 1925

The most important brood years for 1925 were 1919 and 1920, the former furnishing the 6-year fish, which constituted 21 per cent of the run; the latter the 5-year fish, with 72 per cent. Taken together, the product of the two years comprised 93 per cent of the run, to be compared with the 96 per cent in 1924. The remaining 7 per cent in 1925 were largely 4-year fish, of which the 4_3 group (largely of male grilse) was again in greatest numbers. It will be noted that the 5-year fish in 1925 were relatively less numerous than in 1924 (72 per cent instead of 79 per cent) and the 6-year fish more numerous (21 per cent instead of 17 per cent).

The random sampling for the season was on the same scale as in 1924, with daily takes whenever possible throughout the fishing season. Unfortunately, the first half of June is almost wholly unrepresented. Eleven age groups were present at some time during the season, including the 3_1 group, which previously had been observed only in 1917, when two specimens were included in our few samples for that year. Thirty individuals appeared in our 1925 material, with the males twice as numerous as the females. The 3_1 group consists of individuals that proceeded to sea in the fry stage during the season in which they hatched and matured in their third season. The fry migrants in the Karluk usually spend an additional year in the sea, returning as members of the 4_1 group, but in 1925 the latter group contains less than half as many members as the former.

The total number of individuals obtained by random sampling in 1925 was 5,513, which are grouped by age, sex, and length in Table 15. The age groups 5_3, 6_4, and 6_3 are here stated in the order of their importance in the run, their relation represented, respectively, by the percentages 78, 18, and 4. Corresponding figures for 1924 are 81, 14, and 5, and in the abnormal year 1922, 63, 6, and 31.

68335—27——4

TABLE 15.—*Random samplings of the Karluk red-salmon run of 1925, distributed by age groups, sex, and length*

Lengths, in centimeters	Age groups and sex																					Total
	3_1		4_1		4_2		4_3		5_2		5_3		5_4		6_3		6_4		6_5	7_4		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	F	M	F	
43							3						1									4
44							6					1						1				8
45							3					1										4
46							10										1	1				12
47							8				1	1	2				1					13
48					1		4				2	2	3				1	1				14
49						1	4				1	4	1					1				12
50						1	11	1			1	2	1	1		1		5				24
51						1	8				2	7	1				2	1				22
52	1				1	1	18	3			7	13	2	1		1	1	3				52
53						5	30	2			7	17	7	1		1		8				78
54		1			1	10	26	3			17	60	7	1		1	2	6				135
55	3	1		1	4	4	38	2			31	75	12	4		3	1	10	1			190
56	1	3	1		3	13	17	1			33	97	11	1		1	5	18				205
57		1		2	8	7	18			1	35	149	2	1	1	4	4	28				261
58	2	1			3	3	7		1		56	220	5		3	7	4	44				356
59	2	1			6	5	4				77	284	4	1	3	15	9	50			1	462
60	6	1			6	3	1				92	300			7	20	21	66		1	2	526
61	3	1		3	3	2					135	284	1		8	22	26	77			2	567
62	1		2	1	8	2				2	177	245			11	23	40	59			4	575
63	1				2				1	3	194	198			14	16	56	63			3	551
64					1					3	234	126			22	12	56	36			2	492
65					1	1					195	71			6	3	50	28		2	1	358
66			2		1				1		184	22			8	3	39	15		2		277
67					1				1		127	5			7		41	2		1		185
68											48	1			3		17					69
69					1						28				1		13			1		44
70											6						5			1		12
71											2						2					4
72									1													1
Total	20	10	5	7	51	59	216	12	5	9	1,692	2,185	60	11	94	133	397	523	1	8	15	5,513

The appearance of each age group in the run of 1925, and its relative importance throughout the season, is shown in Table 16. From this it is again apparent that in general such groups as have spent the longest time in the sea before maturing enter at the very beginning of the run and develop their greatest strength before the middle of the season, while the reverse is the case with the groups that have spent the shortest period in the sea. The most marked example of this is in the case of the 6_3 and the 6_4 groups. Although they belong to the same brood year and are of the same age, they exhibit opposite tendencies as regards time of running. The 6_3 group runs strongest in June and virtually disappears by the first of August. The 6_4 group, on the contrary, is sparsely represented in the June run and develops its greatest numbers from the middle of July to the close of the season. As the greater part of the growth and development of the fish occurs in the sea, it is not strange that length of residence there, rather than total age, should determine this matter.

The 5_3 group, which stands midway between the two series as regards length of life in the sea, develops no obvious tendency in either direction in the run of 1925.

Table 16.—*Karluk red-salmon run of 1925. Percentages of each age group in random samplings taken throughout the season*

Date	Age groups										
	3_1	4_2	4_3	4_1	5_2	5_3	5_4	5_5	6_4	6_5	7_4
June 1		1.0	1.0			69.0		27.0	2.0		
June 18		1.0			1.0	79.0		16.0	2.0		1.0
June 20		1.0	6.0			63.0		21.0	9.0		
June 22		7.0	1.0			73.0		12.0	7.0		
June 23		9.0			1.0	66.0		13.0	11.0		
June 24 and 27		6.0	4.0			68.0	0.5	15.0	6.0		.5
June 26 and 29		5.0	3.0	0.5		71.0		12.0	8.0		.5
June 30 and July 1		4.0	6.0			71.0	1.0	9.0	8.0		1.0
July 13 and 14	1.0	6.0	1.0			73.0	1.0	5.0	12.0		1.0
July 15 and 16		3.0	.5		.5	65.0	.5	3.0	27.0		.5
July 17 and 18		3.0	2.0	.5	3.0	70.0		3.0	18.0		.5
July 20, 22, and 23		1.6	.7	1.1		73.0		2.0	21.0		.7
July 24 and 25		2.0	1.0	1.0		65.0	.5	1.0	30.0		
July 27 and 28	5.0	2.0	.5			68.0	.5		24.0		
July 29 and 30	1.7	1.3	2.0		.5	73.0		1.3	20.0		
July 31 and Aug. 1		2.0	1.3	.4		77.0		.9	18.0		.4
Aug. 3 and 4			1.0			86.0	1.0	1.5	10.0		.5
Aug. 5 and 6		1.7	.8		.4	66.0	.8	3.0	27.0		.4
Aug. 8 and 10	1.3	1.7	1.7		.8	77.0	.8	.4	15.0		1.3
Aug. 11 and 12	4.0	2.6	3.5	.4		74.0	1.8	.9	11.0		1.8
Aug. 13 and 14		1.0	5.0	.5	.5	78.0		.5	14.0		.5
Aug. 15 and 17		.5	9.0			75.0	1.5	.5	13.0		
Aug. 18 and 19		.5	10.0		.5	68.0	2.0	1.0	18.0		
Aug. 20 and 21	.8	.4	8.0			74.0	.4	.4	16.0		.4
Aug. 22 and 24	.5	.5	8.0	1.0		72.0	2.0		16.0		
Aug. 25 and 26			11.0		.5	68.0	3.0		18.0		
Sept. 7			9.1			58.2	8.2		24.5		
Sept. 7			17.2			52.5	4.0		26.3		
Sept. 8			10.8			50.0	8.3		30.0	0.8	
Sept. 8			5.3			47.4	9.5		37.9		

The age group 5_3, which at all times constitutes the majority of the run, affords a striking example of the increase in length and weight that occurs among its members during the season. The first individuals to appear in the run have registered no growth of the current year on the margins of their scales, which are occupied by the terminal check of the preceding fall and winter. Among later arrivals, the new growth of the year begins to appear in the form of one or two strong, widely separated circuli, which contrast strongly with the fine crowded lines of the winter check, which they surround. These broadly spaced summer rings increase in number among the individuals of the run as the season advances, until at the close of the summer all scales are marked by a well-defined marginal band of broadly spaced rings. Still later, in the fall, these may, in turn, become margined by a few narrowly spaced rings, the beginning of the fall-winter check of the current year.

This regular growth during the season is well shown in Table 17, which gives for the principal age group (5_3) the average lengths and weights of males and females throughout our series of samples. In the series of June averages (as was the case in 1922, but not obviously in 1924) can be noted a slight progressive decrease in both males and females, registered in both lengths and weights. The increase begins with the first of July and proceeds without interruption until September. The question of the adequacy of our samples receives favorable testimony in the close correspondence of males and females throughout the series of their fluctuations, and also in the strict parallelism in average lengths and weights when even minor changes are in question. Each of the four series in Table 17 has been smoothed once by threes.

TABLE 17.—*Karluk red-salmon run of 1925. Average lengths and weights of age group 5_3 throughout season*

Date	Centimeters		Hectograms		Date	Centimeters		Hectograms	
	Males	Females	Males	Females		Males	Females	Males	Females
June 18	59.8	57.1	23.8	20.7	Aug. 5 and 6	63.7	60.7	29.4	25.4
June 20	59.7	57.0	23.8	20.7	Aug. 8 and 10	64.0	60.8	29.8	25.6
June 22	59.4	57.1	23.2	20.6	Aug. 11 and 12	64.2	61.1	30.1	25.7
June 23	59.3	57.0	22.9	20.5	Aug. 13 and 14	64.5	61.3	30.4	26.0
June 24 and 27	58.9	56.7	22.2	20.2	Aug. 15 and 17	64.4	61.5	30.2	26.4
June 26 and 29	59.1	56.7	22.4	19.8	Aug. 18 and 19	64.6	61.7	30.6	26.6
June 30 and July 1	59.3	57.3	23.2	20.8	Aug. 20 and 21	64.7	61.9	30.7	26.7
July 13 and 14	60.7	58.1	25.5	21.9	Aug. 22 and 24	65.2	62.0	31.4	26.7
July 15 and 16	61.8	58.8	27.3	23.2	Aug. 25 and 26	65.2	61.9	31.4	26.8
July 17 and 18	62.4	59.1	28.1	23.6	Sept. 7	65.1	61.9	31.8	26.6
July 20, 22 and 23	62.5	59.4	28.1	24.0	Sept. 7 [1]	65.4	61.9	31.8	26.6
July 24 and 25	62.6	59.9	28.3	24.4	Sept. 8	65.4	61.8	31.8	26.5
July 27 and 28	62.9	60.1	28.8	24.7	Sept. 9	65.3	61.8	31.7	26.6
July 29 and 30	63.3	60.3	29.3	25.1					
July 31 and Aug. 1	63.7	60.4	29.5	25.2	Means	62.8	59.9	28.2	24.2
Aug. 3 and 4	63.9	60.5	29.6	25.4					

[1] Second sample.

KARLUK RED-SALMON RUN OF 1926

The 1926 run has been investigated on the basis of daily sampling, in so far as this proved practicable. Little or no material could be obtained during periods closed to commercial fishing, so the record is incomplete prior to June 15, as well as during week ends throughout the season. The earliest example is dated May 24 and the latest September 14. There are 66 samples, taken on different days, and these contain records of 8,172 individuals. Of these, 78.6 per cent belong to the 5_3 group, 9.1 per cent to the 6_4 group, and 5.8 per cent to the 6_3 group. By age, irrespective of group, our samples contain 81 per cent in their fifth year, 15 per cent in their sixth, 3 per cent in their fourth, and 1 per cent in their seventh year.

The principal brood years for this run, therefore, were 1920 and 1921, the progeny of these two years forming 96 per cent of the run. Concerning 1920, we have little information beyond the size of the commercial catch, which was approximately 100,000 cases. In 1921 there were approximately 1,500,000 spawners. The very large run of 1926, when commercial catch and spawning escapement together aggregated some 4,500,000 red salmon, can properly be attributed to the fact that it had for its two principal brood years 1920 and 1921, with their large spawning reserves. The crowded condition of the spawning beds in 1921 was notable; but in spite of the destruction of eggs, when nests were dug up by a succession of spawners, the resulting brood brought to maturity in 1926 some 3,500,000 5-year fish. When this sum shall have been augmented by the number of 6-year fish that will presently appear in the run of 1927, the showing should be a very favorable one.

In Table 18 we present an analysis of the run based on our series of samplings. Representatives of 14 age groups were present, including several 6_5's and 7_5's, which had not appeared in previous years. We note also that the 4_2's and 5_2's, which develop from fingerlings (usually not numerous) that migrate seaward in their second year, were present in disproportionately large numbers.

TABLE 18.—*Random samplings, Karluk red-salmon run, 1926, distributed by age groups, sex, and length*

Length, in centimeters	Age group and sex																							Total
	3_1		4_1		4_2		4_3	4_4	5_2		5_3		5_4	6_3		6_4		6_5	7_4		7_5		8_4	
	M	F	M	F	M	F	M	M	M	F	M	F	M	M	F	M	F	M	M	F	M	F	M	
31								1																1
39							1																	1
40							1																	1
41																								
42							2																	2
43							4																	4
44							7																	7
45												1												1
46							2																	2
47							2																	2
48							2						1			1								4
49							1					4												5
50						2	1				3	5	1				1							13
51					1		2				3	6	1											13
52					1		2				5	16	1			1	1							27
53					4	3					7	23	1			1				1				40
54		1			1		4				21	24	2			1	1							55
55		1			4	12	1		1		27	54	2		3	2	6							113
56	2				9	8	3			2	44	99	3		1	4	5	1						181
57		2			7	13			1	2	68	186	2	1	10	6	7	1		1				307
58		2		1	4	17				3	106	244	1	2	13	7	23	1						424
59	3	2		3	9	14			1	12	113	303		2	18	6	30			5				521
60	2		1		8	20			1	19	142	382		6	34	9	38		1	3		3		669
61	2		1	2	10	11			2	12	152	493		14	49	13	62			8		1		832
62	2		1	6	11	7			2	14	205	551		12	47	31	68		2	12		1		972
63				9	9	1			5	13	275	494		19	46	30	61		1	4		1		968
64			2	6	9	2			6	10	375	396		27	42	40	55		5	5				980
65			1	1	7				4	2	373	224		19	21	54	17		3	1	2		1	730
66						1			5	2	321	97		16	17	44	17		2	5		1		528
67					2				7	1	257	36		20	7	52	6			1				389
68									5		137	8		5	1	25			1					182
69			1						5		92	3		9	1	7			3					121
70									3		41			6		7			3					60
71									1		8			1		4								14
72											2			1										3
Total	11	8	7	28	96	111	35	1	49	92	2,777	3,649	15	160	310	345	398	3	21	46	2	7	1	8,172

Reviewing the eight years for which we have here presented records variously complete or incomplete, we find that the Karluk race is most diversified in its lines of development, apparently more so than is the case with any other race we have examined. Seventeen distinct age groups have been represented in one or more of these runs, all but three of them being detected in the run of 1926. The complete list is as follows, the principal figure representing the year of its age in which the fish matured and the smaller figure the year of its age in which it migrated seawards: 3_1, 3_2, 3_3, 4_1, 4_2, 4_3, 4_4, 5_2, 5_3, 5_4, 5_5, 6_3, 6_4, 6_5, 7_4, 7_5, 8_4.

For comparison with previous years, we present Table 19, giving the age-group composition of the run, as evidenced by our daily samplings. The dominant group, 5_3, does not vary widely during the season but is relatively most numerous in the spring and late summer, with an intervening period in July when it is obviously less abundantly represented. The next two groups, in order of importance, are 6_3 and 6_4, which follow their usual procedure, the former increasing in abundance as the season progresses, while the 6_3 group is in relatively greater number early in the spring and almost wholly disappears before fall.

The minor groups, in general, make their entrances and exits and are present most abundantly during the periods already indicated for previous runs. The 3^8 and 4_1 groups vary in 1926 from what we have previously observed, inasmuch as they

appear here as late-running fish. The 4_2 and 5_2 groups agree this year in showing no distinct culmination in their run, but in August and September they largely disappear from the run.

TABLE 19.—*Karluk red-salmon run of 1926. Percentages of each age group in random samplings throughout season*

Date	Age groups													
	3_1	4_1	4_2	4_3	4_4	5_2	5_3	5_4	6_3	6_4	6_5	7_4	7_5	8_4
May 24			5	1		4	80		7	2		1		
May 27			3				82		10	4		1		
May 30			1	1		2	83		10	2		1		
May 31			6	1		2	75		15	1				
June 2			1				89		9	1				
June 7			7	1		1	78		9	4				
June 15			4			3	79		14					
June 16			8	1			79		10	2				
June 17			4			1	82		11	2				
June 18			3			5	75		16	1				
June 19			2			2	80		14	2				
June 21			4			2	77		16	1				
June 22			6	3		3	72		13	2		1		
June 23			4	1		2	80		8	5				
June 24			4	3		1	80		10	2				
June 25			5			1	78		13	2		1		
June 26			7	2		3	72		13	3				
June 29			7			5	68		14	6				
July 1			6			3	74		9	7		1		
July 3		2	6			2	74		6	10				
July 6			4	1		1	78		13	2		1		
July 7			5	1		2	81		6	5				
July 8			3			2	73		7	12		2		1
July 10			9			5	67		13	3		3		
July 12		1	8			1	78		7	5				
July 13	1	2	4			7	69		12	5				
July 14			4			8	72		7	8		1		
July 15	1	1	4			4	71		7	12				
July 16		1	6			13	62		5	8		5		
July 17		1				9	71		9	9		1		
July 19			4			4	70		11	8		3		
July 20	2	1	2			4	74		6	8		3		
July 21	3	2	1			3	78		6	7				
July 22		3	3			3	79		3	9				
July 23		1	6				70		4	15		4		
July 24	1		1				74		6	16		1	1	
July 26		1				1	75		2	17		3	1	
July 27			2				85		6	7				
July 28	1					2	83		4	9		1		
July 29	2	1	1			1	83		1	10		1		
July 30							80		8	12				
July 31		2				1	80		3	12		2		
Aug. 2		1		1			81		2	14		1		
Aug. 3		1	1				75		5	17		1		
Aug. 4		1					88		1	9		1		
Aug. 5						1	75		3	18		3		
Aug. 6			1				90		2	7				
Aug. 10							80	1	5	11		2	1	
Aug. 11			1				85		2	10		1	1	
Aug. 12	1	1					85		3	9		1		
Aug. 14	1	4		1		2	79	1		8		3	1	
Aug. 16			1	2		1	78	1	4	11		2		
Aug. 17		1	1	1			81		2	12	1	1		
Aug. 18	1	2					83		3	10		1		
Aug. 19		1					92	1		5		1		
Aug. 20		2	1				86	1		10				
Aug. 21					1		88		1	10				
Aug. 25	1	1	1				84		1	10		2		
Aug. 26				1			84	1	1	13				
Aug. 27	1			1			89			9				
Aug. 28			2				79	1	1	17				
Sept. 1	1	1					82			16				
Sept. 3				1			83	1		15				
Sept. 4							83		1	16				
Sept. 6	1						88			11				
Sept. 7							86			13			1	
Sept. 8			1	1			75		1	21		1		
Sept. 9							81	2		16	1			
Sept. 10							79	1		20				
Sept. 11		1					79		1	19				
Sept. 13							72	2		26				
Sept. 14			2	1			79			17	1			

Careful examination of the sizes attained by the principal age groups in different years may yield data of interest and importance. How slight the differences are from year to year within the limits of the same age group is not generally appreciated. Years are cited in which the fish are said to average very large, as well as other years in which the reverse condition appears; but invariably, when such is the case, an examination of the runs demonstrates that the fish run small in years when a younger age group dominates, and average large when an older and larger group prevails.

If the groups are segregated, however, and their average lengths and weights carefully ascertained, the conviction is quickly formed that we are dealing with a highly standardized race characteristic. From year to year the same group presents average sizes that differ by very small amounts. Usually, however, when the data have been gathered by the same observer, it will be found that the lengths of males and females in the same year vary from the norm in the same direction, and can be checked by parallel differences in the weights. In such cases, where the sampling has been adequate, the differences between one year and the next, however small these may be, are genuine phenomena and in need of explanation.

The dominant 5_3 group of the Karluk run offers abundant material for such investigations; but the data at present available are not adequate. For the early years here reported on we have only limited samples covering only a few days of the runs. Furthermore, the measurements were made by different observers, who had little or no training. However, we shall give a list of the average lengths (Table 20) thus ascertained for the 5_3 group in different years, for such information as, under the circumstances, it can be expected to furnish concerning the extremes of variation to which these average lengths are subject.

TABLE 20.—*Average lengths, in centimeters, of males and females of the 5_3 group in a series of years*

Year	Males	Females	Year	Males	Females
1916	63.0	59.3	1924	62.7	59.1
1917	63.5	61.0	1925	62.9	59.9
1919	64.5	60.3	1926	63.5	61.1
1921	64.4	60.3			
1922	60.9	58.4	General average	63.2	59.9

The only considerable variation from the general average is found in the year 1922, which is noted as having had the poorest run in the history of the Karluk River. Apart from the record of that year, the extremes of variation are only 1.8 centimeters in the case of males and 2 centimeters in the case of the females. With regard to the abnormally small sizes shown for the year 1922, the question arises whether there is any direct connection between the failure of the run of that year and the small size of the fish. Was there a scarcity, during the growth of this brood, in the pelagic organisms on which the red salmon almost exclusively feeds, a scarcity that caused extensive mortality among the colony and stunted the growth of those that survived? A reliable series of measurements, extended over a term of years, may throw light on this important question.

The average lengths and weights of the 5_3 group during each of the days in 1926 on which we secured samples are given in Table 21.

TABLE 21.—*Karluk red-salmon run of 1926. Average lengths and weights of age group 5_3 throughout the season*

Date	Centimeters		Hectograms		Date	Centimeters		Hectograms	
	Males	Females	Males	Females		Males	Females	Males	Females
June 15	61.6	59.2	24.7	22.0	July 30	64.7	62.4	29.4	26.7
June 16	61.4	58.9	24.5	21.8	July 31	65.0	62.4	29.9	27.0
June 17	61.2	59.0	24.4	22.0	Aug. 2	65.5	62.8	30.7	27.5
June 18	60.7	58.8	24.2	21.9	Aug. 3	65.7	62.8	31.1	28.0
June 19	60.8	58.9	24.1	22.0	Aug. 4	65.7	63.0	31.1	28.1
June 21	61.0	58.8	24.2	21.9	Aug. 5	66.0	62.9	31.6	28.0
June 22	60.6	59.4	23.8	21.8	Aug. 6	65.8	63.0	30.8	27.8
June 23	60.6	58.9	23.9	21.8	Aug. 10	65.6	62.9	30.8	27.5
June 24	60.2	58.8	23.6	21.8	Aug. 11	65.1	62.6	29.8	27.0
June 25	60.7	58.8	24.0	21.8	Aug. 12	65.4	62.7	30.5	27.0
June 26	61.1	58.7	24.4	21.9	Aug. 14	65.6	62.9	30.3	27.1
June 29	61.3	58.7	24.7	22.0	Aug. 16	65.8	63.0	30.5	27.0
July 1	61.6	59.1	24.9	22.1	Aug. 17	65.8	63.0	30.5	27.4
July 3	61.6	58.9	24.9	22.3	Aug. 18	65.7	62.8	30.5	27.1
July 6	61.7	59.2	25.1	22.5	Aug. 19	65.8	62.9	30.8	27.1
July 7	61.8	59.8	25.5	23.3	Aug. 20	65.4	62.6	30.4	26.7
July 8	61.8	59.9	25.6	23.4	Aug. 21	65.4	62.5	30.5	26.6
July 10	62.3	60.3	26.2	24.2	Aug. 25	65.3	62.4	30.2	26.3
July 12	63.0	60.8	27.2	24.8	Aug. 26	65.4	62.8	30.3	26.6
July 13	63.1	61.4	27.5	25.6	Aug. 27	65.3	62.6	30.2	26.3
July 14	63.4	61.7	28.0	25.8	Aug. 28	65.4	62.5	30.0	25.9
July 15	63.3	61.6	27.8	25.8	Sept. 1	65.5	62.4	29.1	25.5
July 16	63.7	61.5	28.4	25.9	Sept. 3	65.6	62.4	29.7	25.7
July 17	63.7	61.4	28.3	25.5	Sept. 4	65.4	62.4	29.9	25.8
July 19	64.0	61.3	28.4	25.2	Sept. 6	65.3	62.1	29.2	25.6
July 20	64.1	61.4	28.3	25.3	Sept. 7	65.1	61.9	28.9	25.3
July 21	64.4	61.9	28.5	26.0	Sept. 8	64.9	61.8	28.7	25.2
July 22	64.6	62.4	29.1	26.9	Sept. 9	65.1	61.9	29.2	25.0
July 23	64.8	62.4	29.7	26.9	Sept. 10	64.9	61.6	29.1	24.9
July 24	65.0	62.6	29.9	27.1	Sept. 11	65.0	61.5	29.0	24.8
July 26	64.6	62.3	29.4	26.6	Sept. 13	64.8	61.4	28.5	24.6
July 27	64.6	62.6	29.2	27.0	Sept. 14	65.0	61.5	28.5	24.6
July 28	64.5	62.3	29.4	26.6					
July 29	64.4	62.4	28.9	26.8	Mean	63.9	62.0	28.2	25.2

Again, there is a slight recession in size during the latter half of June, to be followed by a recovery in early July, and this by a rapid increase from the 10th of July on through the remainder of that month and into early August. During the first two weeks of September there is the usual decline in size, registered in males and females alike and in both length and weight. Careful inspection of the table shows clearly that we are dealing in this series with something more than simple growth phenomena during a period of vigorous feeding. A regular succession of events is indicated in this and similar tables for previous years contained in this report. A distinct tendency toward increase or decrease in size, shared by both males and females, is shown for the same period in each year, indicating that in different phases of the run we are dealing with heterogeneous material with different growth histories. For comparison with the succession of sizes that accompany the course of the season in the case of the 5_3 group, we give, in Table 22, the average lengths and weights of the 6_3 and the 6_4 groups for certain periods throughout the season.

TABLE 22.—*Karluk red-salmon run of 1926. Average lengths and weights of age groups 6_3 and 6_4 throughout the season*

	Age group 6_3				Age group 6_4			
	Centimeters		Hectograms		Centimeters		Hectograms	
	Males	Females	Males	Females	Males	Females	Males	Females
June 15–29	63.7	61.7	27.1	24.9	60.3	58.5	23.5	21.5
July 1–31	64.9	62.2	28.7	25.5	63.1	61.3	28.3	25.7
Aug. 2–28	67.0	62.8	31.6	26.0	65.2	62.4	29.6	26.4
Sept. 1–14					65.6	62.1	29.8	25.0

Among the adult salmon that return to the Karluk River to spawn there is always found a larger number of females than males. The proportions differ somewhat in different years, partly due to the number of grilse that enter the run. For the grilse, alone, of all the age groups, show a marked preponderance of male fish. In Table 23 the proportions of the sexes are given for different sections of the run of 1926. It will be noted that during the second half of June and from the middle of July to the end of August the relative numbers of males and females are virtually identical, varying less than 1 per cent during this most important part of the run. During the earlier part of the run, prior to the middle of June, the males show greater abundance, about equaling the females in number. During the latter part of the run, especially in September, the males show a marked increase, slightly exceeding the females for the average of this period. This reversal near the end of the season is not wholly due to the increase in numbers of grilse running at this time, for if we take into consideration only the 5_3 and the 6_3 groups, we find in them also a slight excess of males.

TABLE 23.—*Karluk red-salmon run of 1926. Percentages of males and females in samples during different portions of run*

Date	Males	Females	Date	Males	Females
May 24 to June 18	49.1	50.9	Aug. 14 to Aug. 27	39.8	60.2
June 19 to July 3	39.0	61.0	Aug. 28 to Sept. 11	53.1	46.9
July 6 to July 17	42.1	57.9			
July 19 to July 29	39.4	60.6	Total	43.0	57.0
July 30 to Aug. 12	39.9	60.1			

In Table 24 we give, for purposes of comparison, the proportions of males and females in the three principal age groups during four recent years. We give also the relative proportions of the males and females in the total samples of all age groups taken during those years. It will be noted that the excess of females is greatest in age group 6_3 for each of the four years presented, a condition that may well stand related to the fact that the 6_3 group has spent one more year at sea than have the other two groups and is thus potentially older. Inasmuch as the males show a constant tendency to mature at an earlier age than do the females, it results that early-maturing age groups very generally show a heavier percentage of males than do the older groups.

TABLE 24.—*Percentages of males and females in principal age groups in a series of years*

Year	Sex	Age groups 5_3	Age groups 6_3	Age groups 6_4	Total samples
1922	Males	48.4	42.0	57.3	47.6
	Females	51.6	58.0	42.7	52.4
1924	Males	46.6	44.3	46.8	49.0
	Females	53.4	55.7	53.2	51.0
1925	Males	43.7	41.4	43.2	46.2
	Females	56.3	58.6	56.8	53.8
1926	Males	43.2	34.0	46.4	43.2
	Females	56.8	66.0	53.6	56.8

In the face of this constant inequality of the sexes in mature salmon of the Karluk race stands the fact that among the fingerlings on their seaward migration males and females are in equal numbers, or, if there be a slight inequality, it is in favor of the males. Among 619 fingerlings taken at random in the spring of 1926, 315 were males and 304 females. Among 450 random selections of the spring of 1925, 227 were males and 223 females. Only two alternatives seem to confront us by way of explanation. Beginning their sea life in equal numbers, the males and females may have a different survival value, with a selective mortality acting in favor of the females; or there may be a very considerable precocious development of the males, which may elude us largely because of their small size, and with these eliminated from the commercially valuable fish the preponderance of females would be assured.

ESCAPEMENTS AND TOTAL RUNS, 1921 TO 1926

The weekly escapements during the five years in which the weir has been maintained are given in Table 25. In Table 26 we present data of the runs for these same years. The runs represent the commercial catch plus the escapement. The data for the catch were secured from the three canneries that draw mainly from the Karluk run—the Alaska Packers Association, the Northwestern Fisheries Co., and the Robinson Packing Corporation. The data are complete except for 1921, in which no figures are available for the Robinson Packing Corporation. Their pack for that year is known to have been comparatively small, and it is believed that no great error is brought in by taking the catch of the two other canneries as the total.

TABLE 25.—*Escapement of Karluk red salmon by weeks, 1921 to 1926*

	1921	1922	1923	1924	1925	1926
May 11-17				1		
		60	141	301	19	577
	5,894	418	1,102	4,149	30,249	80,704
June 1-7	16,254	9,921	71,724	86,111	32,733	479,455
	155,097	8,355	28,843	148,417	20,440	437,051
	137,334	57,739	42,169	127,645	263,029	127,537
	195,151	29,897	62,954	64,913	211,021	45,520
June 29-July 5	74,291	46,770	35,647	57,674	34,289	41,516
	72,556	24,366	9,274	39,837	39,927	43,339
	28,668	19,660	3,497	10,882	25,447	34,277
	19,737	6,877	31,491	25,659	24,482	30,300
July 27-Aug. 2	70,954	8,035	24,691	[1] 57,894	64,752	77,956
	96,677	19,403	66,404	[1] 36,281	110,570	101,703
	114,102	7,919	13,036	[1] 61,502	95,862	80,647
	58,867	5,595	48,610	[1] 54,357	19,705	104,139
	79,316	[1] 2,500	38,467		33,797	224,592
Aug. 31-Sept. 6	42,974	[1] 2,500	27,919		200,247	230,498
	143,022	24,343	61,389		74,730	91,136
	14,760	35,618	43,217		100,431	176,939
		61	10,570		51,815	49,609
Sept. 28-Oct. 4		15,721	62,641		182,763	9,448
		29,116	9,110		4,619	43,314
		34,336	1,683			23,145
		236				
Total	1,325,654	384,684	694,579	775,705	1,620,927	2,533,402

[1] Estimated; see text.

TABLE 26.—*Accumulated totals of the runs of Karluk red salmon for each week, from 1921 to 1926, and percentage of the total run for the season that had accumulated to the end of each week*

Date	1921		1922		1923	
	Number of fish, thousands	Per cent of total run	Number of fish, thousands	Per cent of total run	Number of fish, thousands	Per cent of total run
May 4–10	5	----	----	----	----	----
May 18–24	5	0.2	----	0.05	1	0.08
May 25–31	22	.7	10	1.1	73	5.1
June 1–7	177	6.0	23	2.5	102	7.2
June 8–14	315	10.7	94	10.0	211	14.9
June 15–21	544	18.6	139	14.8	347	24.5
June 22–28	765	26.2	216	23.1	422	29.7
June 29–July 5	875	29.9	246	26.2	447	31.5
July 6–12	968	33.9	281	30.0	489	34.4
July 13–19	1,123	38.3	318	34.0	552	38.9
July 20–26	1,379	47.1	362	36.8	659	46.4
July 27–Aug. 2	1,617	55.2	411	43.8	788	55.5
Aug. 3–9	1,848	62.9	453	48.3	851	60.0
Aug. 10–16	2,040	69.4	501	53.5	957	67.5
Aug. 17–23	2,311	79.0	561	59.9	1,050	74.0
Aug. 24–30	2,495	85.0	610	65.0	1,101	77.5
Aug. 31–Sept. 6	2,771	94.6	727	77.6	1,255	88.5
Sept. 7–13	2,872	98.0	838	89.3	1,326	93.5
Sept. 14–20	2,915	99.5	858	91.4	1,346	94.8
Sept. 21–27	2,926	100.0	873	93.0	1,408	99.2
Sept. 28–Oct. 4	----	----	902	96.2	1,418	99.9
Oct. 5–11	----	----	937	99.9	1,419	100.0
Oct. 12–18	----	----	937	100.0	----	----

Date	1924		1925		1926		Average per cent, 1924, omitted
	Number of fish, thousands	Per cent of total run [1]	Number of fish, thousands	Per cent of total run	Number of fish, thousands	Per cent of total run	
May 18–24	4	0.2	30	1.0	81	1.7	0.6
May 25–31	90	4.5	63	2.2	560	12.1	4.2
June 1–7	256	12.8	83	2.9	997	21.6	8.0
June 8–14	426	21.3	346	11.9	1,125	24.3	14.4
June 15–21	545	27.2	598	20.5	1,377	29.7	21.6
June 22–28	634	31.7	710	24.4	1,517	32.6	27.2
June 29–July 5	699	34.9	785	27.0	1,573	34.1	29.7
July 6–12	768	38.4	820	28.2	1,662	36.0	32.3
July 13–19	857	42.8	871	29.9	1,803	39.0	36.0
July 20–26	949	47.5	1,001	34.4	2,012	43.6	41.7
July 27–Aug. 2	1,020	51.0	1,379	47.4	2,300	49.9	50.4
Aug. 3–9	1,115	55.7	1,644	56.4	2,606	56.5	56.8
Aug. 10–16	1,203	60.2	1,809	62.1	2,844	61.5	62.8
Aug. 17–23	[2] 1,410	70.5	1,987	68.0	3,316	71.7	70.5
Aug. 24–30	1,545	77.3	2,266	77.7	3,751	81.3	77.3
Aug. 31–Sept. 6	1,718	85.9	2,342	80.4	4,072	88.3	85.9
Sept. 7–13	1,878	93.9	2,674	91.6	4,474	97.0	93.9
Sept. 14–20	1,910	95.5	2,726	93.4	4,534	98.2	95.5
Sept. 21–27	1,960	98.1	2,909	99.9	4,543	98.5	98.1
Sept. 28–Oct. 4	1,980	99.1	2,913	100.0	4,587	99.5	99.1
Oct. 5–11	1,999	100.0	----	----	4,610	100.0	100.0
Oct. 12–18	2,000	100.0	----	----	----	----	100.0

[1] The percentages here based on an assumed total run of 2,000,000, as explained in the text.
[2] The figures from here to the end of the season were calculated, as explained in the text.

The escapement records are accurate, except for 1922 and 1924. In 1922 the weir was opened for about two weeks—from August 20 to September 5. This was caused by the drifting down on the rack of great numbers of dead pink salmon, which had spawned in the river. Their number was so great that the weir was blocked and washed out, and it was impossible to maintain it. The available records for 1922 have been examined carefully, however, and it is estimated that the escapement during the two weeks could not have been more than about 5,000 red salmon. The last days before the weir was opened the escapement was only a few hundred per day, and the same was true for the week or more after the weir was again in place.

In 1924 the weir was not operated after August 21. Another heavy run of pink mon entered the Karluk River that year, and the weir was washed out as it had been in 1922. The records for 1924, furthermore, are made less reliable than those of the other years as the result of a system of estimating which, through a misunderstanding, was put into practice for a part of the time that the weir was in operation. The following notes were made by the senior author at the time:

> Reds were actually counted through the weir up to and including July 26. From that time until the 21st of August the number was estimated as follows: There were six gates, all of which were opened when the run was so heavy that they were all necessary, or if the run slacked a little, two of the six were closed and fish permitted to pass through the other four. If the numbers were still further reduced, for a time only two were open. The counting was done at two gates only, and the number of red salmon that passed through was multiplied by 3, if six gates were open, or by 2 if four gates were open. The gates at which the counting was done were changed so that any inequality was thus taken care of. The water was clear and there was no difficulty in distinguishing the reds and counting them. Any inaccuracy in this method was due to unequal numbers passing the different gates and not to difficulty in distinguishing reds and counting them. When the run was heavy enough to make it necessary to open other gates than those at which counting was in progress, they ran about equally at all the gates, in the opinion of Mr. Wood.

On account of the lack of complete escapement records for 1924 it has been impossible, of course, to get directly the total run; but for purposes of comparison it is important that we know approximately what this was. The following procedure, therefore, was adopted: In the last column of Table 26 are given the average percentages of the total runs that had accumulated up to the given dates. These averages have been based on the records for the years 1921, 1922, 1923, 1925, and 1926 only. If we assume that the accumulated total for the run up to July 16 (the last date on which the weir was operated) was, in 1924, approximately the same percentage of the total run as in the other years, and from these data calculate the total run, this proves to be very close to 2,000,000 fish. The accumulated total to August 16, 1924, was 1,203,000, and the average percentage of the total runs that had accumulated to that date in the other years was 62.8. Dividing this accumulated total by 0.628 gives us 1,920,000 as the total run. Similar calculations, based on the accumulated totals up to August 9 and 2, give the total run as 1,965,000 and 2,020,000, respectively. We believe, therefore, that the total run in 1924 was, for all practical purposes, close to 2,000,000, and have used this figure in calculating the number of fish in the run subsequent to August 16 and in calculating the accumulated percentages during the part of the season previous to August 16. On account of our method of calculation, the percentages after that date are the same as those in the last column of the table—the average percentages based on the five years for which we have reliable data.

The "run," as we have used the word here, is the catch plus the escapement. In the natural course of events the fish first approach the beach at Karluk Spit, where the commercial fishery is carried on. Those that escape the seines enter the river and may remain in the estuary or passing back and forth between the estuary and the ocean for some time before passing on up to the lake. The weir is situated just above the estuary, and the fish do not pass the weir until they are definitely starting their migration to the lake; and once they have started they do not turn

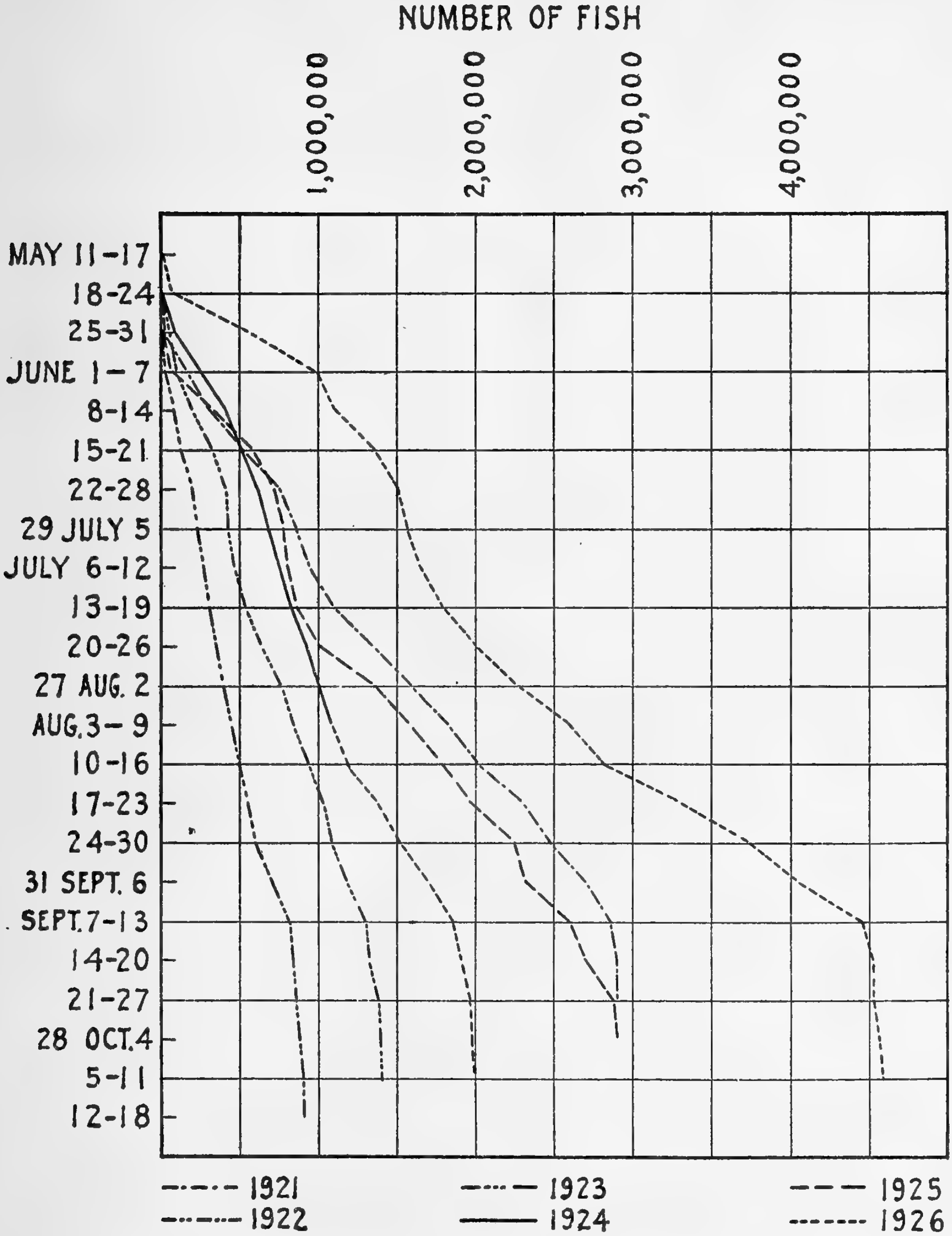


FIG. 33.—Accumulated total number of fish in the run for each week, 1921 to 1926. The dotted portion of the line for 1924 indicates an estimation

back.[10] On account of the time spent in passing through the estuary, between the time the fish first reach the beach and the time they pass the weir, we are not justified in adding the catch and the escapement of the same dates and calling the result the "run" for those dates. Several systems have been tried, and the best evidence we have indicates that an average time of approximately one week elapses while the fish are passing through the estuary. For the purpose of securing the "run," therefore, we have added the catch for each week with the escapement for the following week. The dates given in Table 26 are those on which the catches were made. We

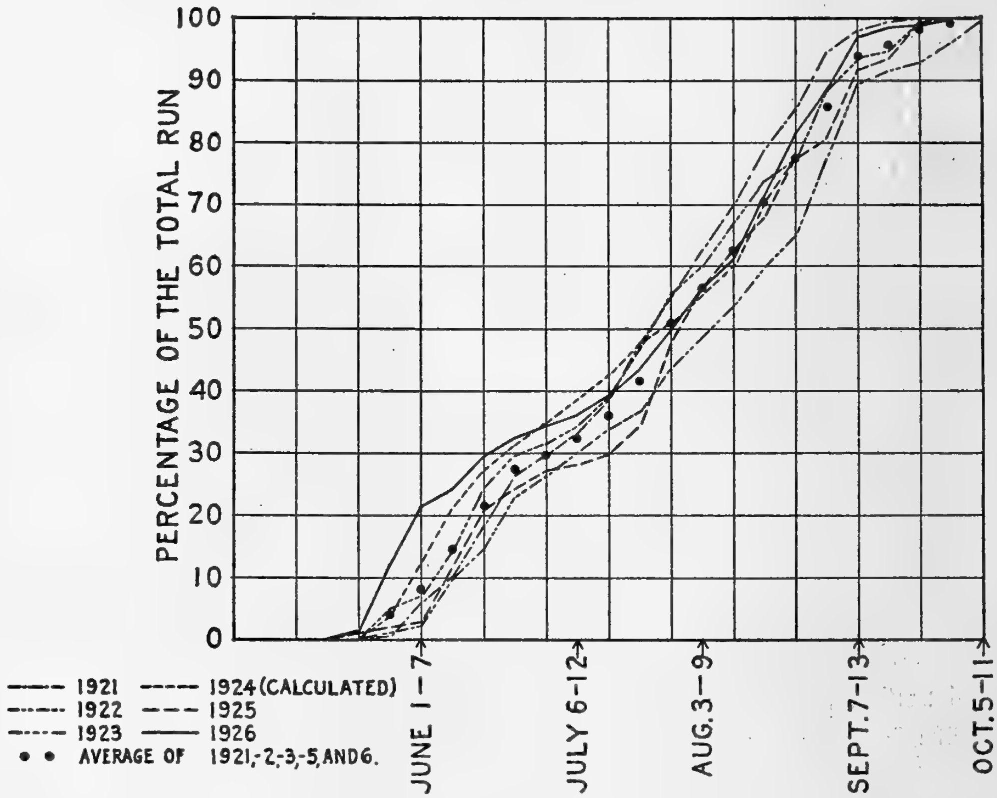


FIG. 34.—Accumulated percentages of the total run for each week, 1921 to 1926

have found that our data, when aggregated into weekly totals, serve every purpose, and we have adopted this system throughout.

The years for which we have detailed data on the runs (1921 to 1926) include completely the last cycle mentioned in the section dealing with the statistical history of the fishery; and it is worthy of special note that, with the exception of 1922, this cycle follows the previous cycles in so far as the relative size of the corresponding years is concerned. This fact indicates to us that here we are dealing with a series of years that, in all probability, are typical of the years of the other

[10] Marking experiments conducted during the summer of 1926 showed that the time required for the migration between the lower weir and the upper weir, situated at the Larsen Bay portage, was only four or five days. It is believed that the entire journey to the lake requires only about a week.

five cycles that have passed since the runs became stabilized following the establishment of the fishery.

Figures 33 and 34 show graphically the data presented in Table 26. Figure 33 gives the number of fish in the accumulated totals for each week for each of the years. Figure 34 gives for each year the weekly accumulated percentage of the total run for that year. In spite of the great differences in the actual size of the runs, there is a remarkable uniformity in the various years in the progress and development of the runs. The curves are invariably steep during June and August, indicating heavy runs during those months. The tendency for the curves to flatten out during July is well marked and clearly reflects the usual poor run of that month. Up to the 13th of September, in most years, the run continues to be good, but it falls off rapidly after that date.

This uniformity in the development of the runs, if supported by a similar study of the runs in future years, will be of very great practical value. From these data it will be possible to tell, comparatively early in the season, just how large the run is likely to be. With this information at hand the regulations can be so adjusted as to provide an adequate spawning escapement, well distributed over the season. At the same time it will be possible for the commercial fishery to plan its season's work to the best advantage and to know approximately, long before the end of the season, what the total pack will be. Even with the few data at hand it seems probable that the total run can be prophesied with some degree of accuracy at least by the end of June. The importance of doing this, from the viewpoint of the fishery administrator and of the commercial fisherman, is so great that it can not be overestimated.

BASES FOR PREDICTION OF FUTURE RUNS

Whatever may be the cause of the extensive fluctuations that occur in the size of consecutive salmon runs, there can be no question that they are responsible, during many seasons, for very serious economic loss. The salmon industry is dependent on supplies of raw material that are available during short periods of the year, varying in different districts from a few weeks to a very few months. The Bristol Bay District furnishes an example of an extremely short fishing season of four weeks, while the Karluk region stands near the opposite extreme with a season of three months; but in all regions, long or short, complete preparations for the season's operations have to be made months in advance. Funds must be secured, labor contracted for, boats, fishing gear, and supplies of every description must be obtained on a scale large enough to permit a maximum pack if the season proves favorable in its supplies of salmon. If, for any reason, only a meager run develops, the losses may well mount into the millions of dollars. Much of this loss could be avoided if the unfavorable character of the season could be foretold. Operations could be conducted on a reduced scale, or, in extreme cases, they could be temporarily discontinued.

The direct economic saving that would result from reliable predictions of the runs would be even less important than the indirect results along the line of conservation. Whatever the immediate cause of a failure in the run, this disastrous condition will be perpetuated and intensified if during that season fishing opera-

tions are conducted with their usual intensity, accompanied by the customary feverish raking and scraping to secure the largest pack possible under unfavorable circumstances. If the nature of the season could be predicted with a fair degree of certainty, it would be possible to avoid immediate serious operating losses and at the same time aid in standardizing the runs by securing a more nearly adequate spawning escapement even in a poor year.

One of the foremost among the objects to be sought in a fisheries conservation program, therefore, is a reliable basis for prediction concerning the magnitude of future fish supplies. This need is appreciated in all fishery investigations, whether of salmon or herring, halibut, cod, or mackerel. The significance of the intensive studies of dominant year groups, of which we hear so much, lies here. In the case of the salmon, in comparison with other marine fisheries, we enjoy certain obvious advantages in developing a technique of prediction, together with certain disadvantages equally obvious. Among the advantages we find the salmon segregated in relatively small, geographically limited, self-perpetuating races, the entire spawning colonies of which annually may be passed in review, and permit detailed quantitative and qualitative determinations impossible in the case of species that spawn in the sea. Among the disadvantages stands prominently the fact that the salmon are relatively short-lived, and, after the young enter the sea, are for the most part wholly inaccessible until the year in which they reach maturity, seek their spawning beds, and invariably die. We are largely deprived, therefore, of the important aid to prediction that can be obtained by the investigation of dominant or defective year classes, which can be seen to pass through the herring or other fisheries over a term of years. With the salmon these are available only in a very minor way, which will be discussed later in these pages in connection with the possible significance of grilse runs of different magnitude.

The great advantage to be found in the use of year classes for purposes of prediction, whether abnormally large or small, lies in the fact that by the time these are sufficiently defined the major part of the hazards that confront every brood are already past, and we have to do with the survivors of a long series of attacks to which the brood has been subject in every stage from the egg to the mature fish. Every hazard means also an uncertainty, and with the passing of the hazards the uncertainties grow less and less. The most reliable evidence concerning the final condition of the brood is that obtained from the years immediately preceding maturity, while the earlier years give progressively less that is authoritative. Still less significant than the fry is the number of eggs produced during the season responsible for the brood; and of still less value, the number of spawning pairs. We believe, however, that all of these, when quantitatively known, have significance and value, though in varying degree, and it is this that justifies us in undertaking investigations concerning the relation that will be found to exist between the number of spawning parents, at one end of the chain, and the final number of their mature progeny, at the other. We consider it probable that we shall discover a significant correlation.

We have no doubt, however, that if we could substitute for the number of spawning fish the number of resulting fry emerging from the gravels, or, of still higher value, the number of fingerlings of the brood that accomplish their seaward migration, we would be in possession of data of far greater predictive value. We have

focused our attention, first, on number of parents, because of the immediate practical value of the results to be obtained on pressing problems of conservation. The Bureau of Fisheries is empowered to secure an adequate escapement of spawning fish and can find means for attaining this end; but it has no influence over the seasonal conditions that favor or are detrimental to egg-laying, incubation, and hatching, or to the incidence of disease, the attacks of parasites, or the depredations of predatory forms, all of which exact a heavy toll during life in fresh water.

Although the first duty of the bureau is to assure adequate spawning reserves, we shall not neglect other data that can be obtained in the prosecution of our investigations, nor the testing of these as to their predictive value. Annually we shall secure the census of fish that ascend the river to spawn. This does not furnish the actual number of spawning fish, inasmuch as many die without spawning on reaching the lake or its tributaries; but it is believed closely to approximate the number of actual spawners and represents the closest determination of their number of which we are capable. As to the subsequent history of the brood, we entertain no hope of being able to estimate the numbers of fry emerging from the gravels, nor of the numbers of fry and fingerlings during their residence in the lake. Attempts to estimate the proportions of the downstream migration appear more promising, although the difficulties in the way seem formidable. After the fingerlings have reached the sea, the only clues that can be obtained as to the size of the growing colonies are such as are furnished by the precociously maturing grilse. The No. 1 grilse—those that mature during the same season in which they reach the sea (figs. 25, 26, and 27)—have little or no value for this purpose. They are recruited almost exclusively from a small group of fingerlings, which migrate seaward in their fourth year, and such predictions as could be based on the numbers in which they appear from year to year would furnish evidence concerning only the 6_4 and 7_4 groups, which furnish relatively unimportant constituents of the run. To be of any considerable value, predictions must deal with the probable size of the 5_3 group, which normally comprises about 80 per cent of the run. This group is largely withdrawn from observation from the time when it descends the river to the sea, in its third year, until it returns as 5-year fish. Only a small percentage of it matures precociously one year earlier and returns to form the 4_3 group.

This group varies greatly in size with different years, and the question for us to solve is whether the magnitude of its occurrence in any year gives reliable evidence of the size of the brood to which it belongs, which will largely mature the following year as group 5_3 and will form the bulk of that year's run. If approximately the same percentage of each brood matures precociously as 4_3 fish, the numbers of the latter will have predictive value; but if the percentage varies widely in response to external conditions that differ from year to year and affect the age of maturing, the number of 4_3 grilse can not be relied on as an indicator of the size of the next year's run. This important question can be answered only after observations extending over a term of years.

A good example of the manner in which we seek to make use of the lines of evidence above described is found in our attempts to predict the probable size of the 1927 Karluk run. As we have already indicated, these lines of evidence are at present to be considered as on trial. They are subjects for investigation and are

68335—27——5

chosen as the most promising fields for predictive research. Not until they have been subjected individually to the crucial test of extended experimentation shall we be in a position to indicate the degree of dependence that can safely be placed in them. At the present stage of progress they form the only basis we have for prophecy and can be used tentatively and with caution for such value as they will be found to possess.

The 5-year fish, members of the 5_3 group, that can confidently be expected to constitute the great majority of the 1927 run developed from eggs laid down during the summer and fall of 1922. They hatched during the season of 1923 and remained in residence in Karluk Lake until the spring of 1925, when, in company with other groups of fingerlings, both younger and older, they descended the river to the sea in a pronounced wave of migration. Nothing further was seen of these 3-year fingerlings until the appearance in the run of 1926 of a certain number of individuals that had separated themselves from their companions and had matured at the early age of 4 years (the 4_3 group), while the great majority of their fellows remained behind in the sea for further growth and development.

We have available, then, as indicators for the run of 1927, (1) the number of spawning fish counted through the weir in 1922; (2) the size of the downstream migration, as observed (but in no way quantitatively determined) in 1925; and (3) the abundance of 4_3 grilse in the run of 1926. We shall consider these in their order.

1. The red-salmon run of 1922 to the Karluk River was one of the poorest of which we have any record. For only one other year since the industry was firmly established (that of 1914) has there been an equally poor commercial yield. More important than the commercial take is the spawning escapement, which in 1922 amounted to 383,684 fish. This count, however, did not include the escapement during a period from August 20 to September 4, during which the counting weir was unable to operate because it was blocked by dead humpback salmon that had spawned above the weir and drifted down upon it. Judging from the condition of the run prior to August 21 and subsequent to September 4, a liberal estimate of the fish that ascended the river during the 15 days in which the weir did not function would give a sufficient number to raise the total spawning escapement for the season to 400,000 fish. This is to be compared with the escapement in 1921, which totaled approximately 1,500,000 fish. The returns of the 1921 spawning thus far obtained indicate a probable rate of increase of three to one. If this ratio should hold with some degree of approximation for the spawning of 1922, the total yield of that brood would be 1,200,000 fish. Should 80 per cent of these run as 5-year fish in 1927, according to expectation, they would total 960,000, and the 4 and 6 year fish that would accompany them from other spawnings might be expected to raise the total run to a figure not exceeding 1,500,000. It will be noted that this estimate is based on the assumption—which our present experience is too limited to justify—that the ratio of increase in the Karluk, from spawning colony to mature progeny, will, with each year, approximate three to one. The experience of 1927 will be most valuable as throwing light on the extent to which this ratio fluctuates in different years.

2. No attempt was made in the spring of 1925 to estimate the number of downstream migrants, which were largely derived from the 1922 spawning. They could

be observed about the weir, through which they had no difficulty in passing, and were especially conspicuous in the brackish lagoon below the weir, where they seemed to linger a brief while, accustoming themselves to the denser medium. In the lagoon the red-salmon fingerlings have the habit of leaping freely into the air, thus giving some clue to the distribution of schools within the lagoon and to the density of the population. The general belief of all observers in 1925 was that the fingerling migration compared well with previous years and may have been larger than was observed in 1924; but the basis for this judgment obviously was inadequate, and little dependence can be placed on it. If we were dealing with well-ascertained data, which indicated a fingerling migration in 1925 equal or superior to that of 1924 (the foundation of the run of 1926), we could ignore the dismal predictions based on the very limited spawning reserve of 1922 and could look forward confidently to a successful run in 1927. In that case we should be forced to conclude that the relatively few spawners of 1922 had encountered extraordinarily favorable conditions and had produced a colony of fingerlings far beyond the ordinary. The possibility of such an occurrence emphasizes the high value of a fingerling estimate, even if this be only roughly approximate; but the general impressions concerning the fingerlings of 1925 are not of sufficient validity to do more than inject a certain element of doubt into the situation beyond that which was already present.

3. There remains to consider the evidence obtainable from the size of the 4_3 grilse group present in the 1926 run. As we have shown elsewhere, these grilse appear in limited numbers in the early part of each run, then dwindle in numbers or wholly disappear during the middle of the season, and reappear in a run of considerable proportions late in August and during the first half of September. Our observations cover the years 1924, 1925, and 1926, and are derived in part from random sampling throughout the season, but chiefly from special studies of their relative abundance carried on late in the season. These studies were also based on the method of random sampling, but on a much larger scale than was found adequate for other purposes. We shall confine our attention here to the special examination of the catch made during certain days in September of each of the three years, the fish being taken at random from the fish bins at Larsen Bay or Uyak.

In 1924, on September 8, 300 fish were taken at random from the bins at Larsen Bay, 44 of which (14.7 per cent) were of the 4_3 group. On September 9, 300 more were examined, of which 45 (15 per cent) were 4_3's. A third sample, of 300, was taken on September 11, which proved to contain 32 of the 4_3 group (11 per cent), and a fourth sample, on September 12, of 200 fish, contained 25 (12.5 per cent). Of the above 1,100 fish examined from September 8 to 12, there were 146 4_3's, amounting in all to 13.4 per cent; 90 per cent of these were males and 10 per cent females.

In 1925, similar series of determinations were made on September 8, 9, and 11. Five hundred were examined on each of the first two dates and 300 on the last, and the percentages of the 4_3 group ran, respectively, 11, 25, and 15. In view of the wide disparity of the three dates, it would have been desirable to extend our series in both directions from the dates selected; but limitations placed on the fishing season that year made further experiments along this line impossible. We are left in doubt, therefore, whether the 25 per cent observed on September 9 or the 11 and

15 per cents of September 8 and 11 stand closer to the general average of this group during that portion of the run. The general average for the 1,300 individuals that we examined in 1925 is 17.3 per cent of 4_3's. Had we attempted an estimate of the 1926 run, based on the relative number of 4_3 grilse present in 1924 and 1925 and the ascertained run of 1925, the above figures would have warranted us in predicting a somewhat larger run in 1926 than we had in 1925, but not as large as the 1926 run actually proved to be. If the 1925 percentage of grilse had been 22 instead of 17.3, this would have furnished us a basis for a fairly accurate forecast of the 1926 run. However, admitting the incompleteness of our data for both 1924 and 1925 and the improbability that even with adequate determinations of the numbers of grilse we should have a basis for any closely accurate predictions, our experience with the 4_3 grilse counts in 1924 and 1925 and the corresponding 5_3 returns in 1925 and 1926 is favorable to the theory that a fairly definite relation exists between the number of younger fish occurring in the run of one year and the size of the run of the following year. The experience of only two years, however, is insufficient foundation for any high degree of confidence, and we must look to the results in 1927 and susequent years either to confirm or to refute the theory we tentatively entertain.

The run in 1927 will offer crucial evidence in this direction. As we have seen, the spawning reserve of its principal brood year, 1922, was very limited and apparently inadequate to produce a normal run. On the other hand, such superficial observations of the fingerling migration of 1925 as were made gave favorable indications, although these were not of such character as to inspire confidence. We have now to consider the 4_3 grilse run of 1926 as our third basis for prediction, and it may be stated at the outset that it was almost nonexistent. Appreciating the significance of these data, a much more extensive series of determinations was made in 1926 than in either of the two previous years. The run was sampled on September 1, 3, 4, 6, 8, 9, 10, 11, and 15, one thousand individuals being examined on each of those dates, except the 3d, the 11th, and the 15th. Five hundred, each, were examined on the 3d and 11th, and 700 on the 15th. The total number included in this test, therefore, was 8,700. It is believed this sampling was entirely adequate, especially in view of the comparatively little variation in the results from day to day. On only one day (the 15th) was the number of the 4_3 group present as high as 1 per cent of the sample taken. On the other 9 days the percentages varied from three-tenths to nine-tenths of 1 per cent, with no obvious trend. The total number observed was 48, of which 41 were males and 7 females. The average percentage of the 4_3 group present in the run during the first half of September was thus only fifty-five one-hundreths of 1 per cent. When these figures are compared with the 13.4 per cent in 1924 and the 17.3 per cent in 1925 it is seen that the grilse of 1926 corroborate the evidence derived from the limited spawning of 1922 and give no grounds for hope of a normal return of 5_3's in 1927.

As we have stated above, such hope as exists must be based on the general impression of an extensive fingerling migration in 1925. These fingerlings were largely the progeny of the scanty 1922 spawning, and we have no knowledge of any physical or other conditions in 1922 that could be considered extraordinarily favorable for the production of a large crop of fingerlings from a strictly limited number of eggs. Nevertheless, such conditions may have existed.

As having a possible bearing on this subject, we may recall that 1922 was one of the big cycle years for the pink or humpback salmon. The run of that year was extensive, and spawning occurred not only along the river but on virtually all the important red-salmon beds of the lake system, where they outnumbered the red salmon at least 5 to 1. The progeny of the 1922 pink run comprised the banner run of that species to the Karluk River in 1924, when they were vastly more numerous, even, than in 1922. Obviously, then, the conditions for the successful spawning of pinks in 1922 were extraordinarily favorable and the yield disproportionally large, yet their eggs were laid down in the same gravels with the red salmon and at the same time. It becomes a most interesting question whether conditions favorable to one species under such circumstances would be equally favorable to the other. If a red-salmon run of normal proportions should, after all, develop in the Karluk in 1927, that would go far toward answering this question in the affirmative. Such an answer would lead us to entertain grave apprehensions for the Karluk red-salmon run in 1929, for the pink salmon spawning of 1924, in spite of its almost unparalleled intensity, was a complete failure. No pink run whatever resulted in 1926. If a similar fate befell the 1924 red-salmon eggs, we shall have an extremely limited fingerling migration in 1927 and a failure of the run of 1929. We have as yet, however, no observational basis for anticipating in these two species corresponding success or failure in any given year, even when they share the same spawning beds.

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SALMON-TAGGING EXPERIMENTS IN ALASKA, 1926

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INTRODUCTION

Continuing the series of salmon-tagging experiments that have been conducted in Alaska since 1922, approximately 13,000 salmon were tagged during the summer of 1926 in the channels of southeastern Alaska. The methods employed have been adequately described in previous publications.[1] During 1926 a special effort was made to supplement the experiments of 1924 and 1925 in southeastern Alaska; and, in general, the tagging that was done early in the season in 1926 was carried out in localities where it had been done late in the other years, and vice versa.

In the report on the experiments of 1924 and 1925 a list of localities from which returns had been obtained was given. The 1926 returns came from many of these localities and from a few not contained in the list. It does not seem necessary to repeat the list in this report, as it is readily available to anyone interested; but we present the following supplemental list of localities that do not appear in the previous list, but from which returns were reported in 1926. Any of the places mentioned in this report can be identified from the two lists.

MINOR LOCALITIES FROM WHICH TAGGED FISH WERE RECORDED

Alder Grove. Three miles north of Lime Point, Hetta Inlet.
Annette Point. Southern point of Annette Island, Clarence Strait.
Arboleda Point. Northwestern point of Suemez Island, Bucareli Bay.
Auke Bay. Mainland shore, northeastern end of Stephens Passage.

Baker Island. Bucareli Bay.
Bay Point. Prince of Wales Island, 1 mile southeast of Point Colpoys. Western point of entrance to Farragut Bay.
Bradfield Canal. Indenting the mainland north of Cleveland Peninsula.
Browson Island. Ernest Sound, southeast of Etolin Island.
Burke Channel. Queen Charlotte Sound, British Columbia.

[1] Experiments in Tagging Adult Red Salmon, Alaska Peninsula Fisheries Reservation, Summer of 1922. By Charles H. Gilbert. Bulletin, U. S. Bureau of Fisheries, Vol. XXXIX, 1923-1924 (1923), pp. 39-50, 1 fig. Washington. Second Experiment in Tagging Salmon in the Alaska Peninsula Fisheries Reservation, Summer of 1923, By Charles H. Gilbert and Willis H. Rich. *Ibid*, Vol. XLII, 1926 (1925), pp. 27-75, 12 figs. Salmon-Tagging Experiments in Alaska, 1924 and 1925. By Willis H. Rich. *Ibid* (1926), pp. 109-146, 1 fig.

Caamaño Point. Behm Canal, southernmost point of Cleveland Peninsula.
Cape Fox Island. Cape Fox, Dixon Entrance.
Carroll Island, Frederick Sound. Southern end of Admiralty Island.
Carroll Point. Entrance to Carroll Inlet, southern shore of Revillagigedo Island.
Caution Point. Southern point of entrance to Whitewater Bay, Chatham Strait.
Cedar Point. (Three listed, exact locality shown in tables.)
Chichagof Pass. Between Etolin and Woronkofski Islands.
Chickamin River. Entering Behm Canal near latitude 55° 51′.
China Hat Island. Just west of Stevens Island near the mouth of the Skeena River, British Columbia.
Clover Bay. Eastern shore of Prince of Wales Island, just north of Cholmondelay Sound.
Club Rocks. Three miles south of Cape Northumberland, Dixon Entrance.
Coffman Island. At southern entrance to Kashevarof Passage, northeastern shore of Prince of Wales Island.
Concks Creek. Near Wrangell.

Daisy Island. In Kasaan Bay, western shore of Clarence Strait.
Dall Bay. Two miles northeast of Dall Head, Gravina Island.
Danger Point. (Two listed.) 1. Mitkof Island, Wrangell Strait. 2. Southern point of entrance to Kootznahoo Inlet, Admiralty Island.
Datzkoo Harbor. Dall Island.
Deepwater Point. Northern point of entrance to Woewoodski Harbor, Frederick Sound.
Division Point. East-northeast of Mud Bay.
Dog Island. Northern shore of Duke Island.
Dry Bay. Eastern shore of Stephens Passage, latitude 57° 37′.
Dry Strait. Between Mitkof Island and the mainland.

Edye Passage. North of Porcher Island, British Columbia.
Eliza Harbor. Admiralty Island, Frederick Sound.
Emerald Bay. Ernest Sound.

False Bay. Eastern shore of Chichagof Island, Chatham Strait.
False Island. Northern shore Peril Strait, opposite Rodman Bay.
Favorite Bay. Head of southernmost arm of Kootznahoo Inlet, Admiralty Island, Chatham Strait.
Fish Creek. Douglas Island, north of Fritz Cove.
Fishery Point. Western shore of Admiralty Island, Chatham Strait.
Five Mile Creek. Five miles north of Petersburg, on Kupreanof Island.
Francis Anchorage. In Farragut Bay, Frederick Sound.
Freshwater Bay. Eastern shore of Chichagof Island, Chatham Strait.
Fritz Cove. Western end of Douglas Island.
Frosty Bay. Seward Passage.

Garnet Point. Southern point of Kanagunat Island.
George Islands. Entrance to Port Althorp, Cross Sound.
Glass Peninsula. Between Seymour Canal and Stephens Passage, Admiralty Island.
Grace Harbor. Dall Island.
Grant Cove. Northern end of Gravina Island.
Grindall Island. At entrance to Kasaan Bay.

Helm Bay. On Cleveland Peninsula, Behm Canal.
Herring Bay. Frederick Sound, southern shore of Admiralty Island.
Hotspur Island. Between Annette and Duke Islands.
Howkan Narrows. Between Dall and Long Islands.
Hugh Point. Southernmost point of Glass Peninsula.
Humpback Bay. Porcher Island, British Columbia.
Hunter Bay. Prince of Wales Island, opening into Cordova Bay.

Indian Point. Northern point of entrance to Naha Bay, Behm Canal.
Ingraham Bay and Point. Southeastern shore, Prince of Wales Island, latitude 55°.
Inian Cove. Northwest coast of Inian Island.
Inian Pass (South). Icy Strait, between Inian Island and Chichagof Island.

Kadake Bay. First bay north of Port Camden, Keku Strait.
Kake. Village in northeastern part of Kupreanof Island.
Kasaan Point. The north point of entrance to Skowl Arm of Kasaan Bay.
Kelp Bay. Northeastern shore of Baranof Island, Chatham Strait.
Kelp Point. (Two listed.) 1. Dundas Island, British Columbia. 2. Etolin Island, Clarence Strait.
Kennedy Island. Just south of Skeena River, British Columbia.
Kitwanga. Town on the Skeena River, British Columbia.

Lemesurier Island. Icy Strait, at entrance to Glacier Bay.
Lime Point. Prince of Wales Island, east of Sukkwan Island. (Incorrectly printed in previous list as Line Point.)
Lisianski Inlet. Northwestern part of Chichagof Island, opening into Lisianski Strait and thence into Cross Sound.
Long Island. Kaigani Strait.
Lyman Anchorage. Western shore of Clarence Strait, Kasaan Peninsula, Prince of Wales Island.

MacNamara Point. Zarembo Island, northeast point of entrance to Clarence Strait.
Mary Island. North of Duke Island, Revillagigedo Channel.
Massett Inlet. Graham Island, British Columbia.
Meyers Chuck. Clarence Strait, Cleveland Peninsula east of Lemesurier Point.
Middle Point. Douglas Island.
Morris Reef. Chatham Strait at eastern entrance to Peril Strait.
Mosman Inlet. Etolin Island, Clarence Strait.
Mud Bay. Northern shore of Chichagof Island, Icy Strait.
Murder Cove. Southern end of Admiralty Island.

Napean Point. Eliza Harbor, Frederick Sound.
Nelson Cove. West shore Gravina Island, Clarence Strait.
Nesbitt Point. Southernmost point of Zarembo Island.
North Pass. North of Lemesurier Island, Icy Strait.
Nunez Point. Southeast point of Bean Island, near Cape Chacon, Dixon Entrance.

Observatory Inlet. Upper continuation of Portland Inlet, British Columbia, above the mouth of the Nass River.
Outer Point. Western point of Douglas Island, Stephens Passage.

Parker Point. Western shore Admiralty Island, Chatham Strait.
Peninsula Point. Tongass Narrows, Revillagigedo Island. (Another in Chatham Strait.)
Percy Islands. Near Sealed Passage, Clarence Strait.
Pinta Cove. South shore of Icy Strait, eastern side of Point Adolphus.
Polk Island. North of Ingraham Bay, southeastern shore of Prince of Wales Island.
Port Essington. Skeena River, British Columbia.
Prince Rupert. Near the mouth of Skeena River, British Columbia.

Raymond Cove. Southeastern shore of Cleveland Peninsula, Behm Canal.
Rocky Bay. Etolin Island, opening into Clarence Strait.
Rocky Bay. Thatcher Point, southern point of eastern entrance to Peril Strait.
Rocky Point. On the mainland, south of Excursion Inlet, halfway between Excursion Inlet and Rocky Island.

Saginaw Bay. Northwestern shore of Kuiu Island, Frederick Sound.
San Christoval Channel. Bucareli Bay.
San Juan Bautista Island. In Bucareli Bay, west coast of Prince of Wales Island.
Santa Anna. Bay Point and cannery, mainland shore of Ernest Sound, latitude 56°.
Seward Passage. Ernest Sound between Deer Island and the mainland.
Shelter Cove. Northern end of Stephens Passage.
Shelsey River. In British Columbia, tributary to Taku River.
Shipwreck Point. On northeastern shore of Cordova Bay.
Shoal Point. North end of Douglas Island.
Skin Island. Near entrance of Cholmondeley Sound, Clarence Strait.
Smith Island. Off the mouth of the Skeena River, British Columbia.
Snettisham Inlet (or Port). Indenting mainland coast of Stephens Passage.
Sommerville Channel. Portland Inlet, British Columbia.
Sophia Point. Eastern point of entrance to Port Frederick, Icy Strait.
Spasskaia Bay. Northern shore of Chichagof Island, Icy Strait.
Spencer, Cape. Northwestern point of entrance to Cross Sound.
Stag Bay. Lisianski Strait, indenting the west shore of Chichagof Island.
Strait, Cape. Northeastern shore of Lindenberg Peninsula, Kupreanof Island.

Taku Point. On the eastern shore of Taku Inlet.
Tenakee. Village on eastern shore of Tenakee Inlet, Chichagof Island.
Tugwell Island. Northwest of Digby Island, Chatham Sound, British Columbia.
Twelve-mile Arm. Kasaan Bay, Prince of Wales Island.
Twelve-mile Creek. Twelve miles north of Petersburg, on Kupreanof Island.

Ulitka, Cape. Noyes Island.
Unuk River. Burroughs Bay, mainland north of Revillagigedo Island.

Vallenar Point. Northern end of Gravina Island.
Village Point. (Three listed.) 1. Annette Island. 2. Chilkat Inlet. 3. Chaik Bay, Admiralty Island, Chatham Strait.

Wilson Cove. Southeastern shore, Admiralty Island.

Young Bay. Northern shore Admiralty Island, Stephens Passage.
Young Cove. Howkan Strait, Dall Island, Cordova Bay.

Zayas Island. Dixon Entrance, just west of Dundas Island, British Columbia.

The record of the tags attached in 1926 is given in Table 1.

TABLE 1.—*Tags attached in southeastern Alaska, 1926*

Experiment No.	Serial Nos.	Number of fish tagged	Species	Locality	Date
1	1-200	62 50 19 69	Red Coho Pink Chum	South of Foggy Point	June 24
2	201-498	159 58 2 77	Red Coho Pink Chum	Garnet Point, Kanagunut Island	June 25
3	499-950	233 56 48 113	Red Coho Pink Chum	Midway between Tree and Foggy Points	June 30
4	951-1500	307 74 68 99	Red Coho Pink Chum	Garnet Point	July 1

TABLE 1.—*Tags attached in southeastern Alaska, 1926*—Continued

Experiment No.	Serial Nos.	Number of fish tagged	Species	Locality	Date
5	1501–1800	37	Red	Nelson Cove, west shore of Gravina Island	July 6
		52	Coho		
		169	Pink		
		42	Chum		
6	1801–2160	31	Red	2½ miles north of Nelson Cove	July 7
		64	Coho		
		119	Pink		
		145	Chum		
7	2161–3200	705	Red	Point Colpoys, Sumner Strait	July 10
		61	Coho		
		259	Pink		
		11	Chum		
8	3201–4200	5	Red	4 miles northeast of Cape Bendel, Frederick Sound	July 15
		1	Coho		
		978	Pink		
		16	Chum		
9	4201–5200	4	Red	do	July 16
		2	Coho		
		944	Pink		
		49	Chum		
10	5201–6000	4	Red	do	July 17
		4	Coho		
		774	Pink		
		16	Chum		
11	6001–6500	1	Red	do	July 18
		481	Pink		
		18	Chum		
12	6501–6800	17	Red	5 miles northeast of Parker Point, Chatham Strait	July 20
		1	Coho		
		274	Pink		
		8	Chum		
13	6801–7100	22	Red	do	July 21
		1	Coho		
		271	Pink		
		6	Chum		
14	7101–7500	8	Red	do	July 22
		1	Coho		
		382	Pink		
		8	Chum		
15	7501–7800	7	Red	Inian Cove, Inian Island	July 24
		3	Coho		
		290	Pink		
16	7801–8300	17	Red	do	July 25
		3	Coho		
		476	Pink		
		3	Chum		
17	8301–8600	55	Red	Northwest side of Inian Island	July 26
		9	Coho		
		233	Pink		
		3	Chum		
18	8601–8900	6	Red	do	July 27
		2	Coho		
		289	Pink		
		3	Chum		
19	8901–9200	17	Red	do	July 28
		17	Coho		
		261	Pink		
		5	Chum		
20	9201–9500	25	Red	do	July 29
		13	Coho		
		255	Pink		
		7	Chum		
21	9501–9800	189	Red	West shore of Douglas Island	July 31
		25	Coho		
		73	Pink		
		12	Chum		

TABLE 1.—*Tags attached in southeastern Alaska, 1926*—Continued

Experiment No.	Serial Nos.	Number of fish tagged	Species	Locality	Date
22	9801–10200	94	Red	West shore of Douglas Island	Aug. 1
		25	Coho		
		211	Pink		
		70	Chum		
23	10201–10600	103	Red	Southwest shore of Douglas Island	Aug. 2
		23	Coho		
		262	Pink		
		12	Chum		
24	10601–11000	130	Red	do	Aug. 3
		17	Coho		
		248	Pink		
		5	Chum		
25	11001–11500	4	Red	Stone Rock Bay, Clarence Strait	Aug. 9
		12	Coho		
		479	Pink		
		5	Chum		
26	11501–12500	45	Red	West side of Long Island, Kaigani Strait	Aug. 10
		20	Coho		
		919	Pink		
		14	Chum		
27	12501–13100	10	Red	do	Aug. 11
		26	Coho		
		560	Pink		
		4	Chum		

RETURNS FROM EXPERIMENTS NEAR CAPE FOX

Four experiments were conducted at this point, on June 24, 25, and 30 and on July 1. Nearly 1,500 fish were tagged, including reds, cohos, pinks, and chums. Because of the fact that the experiments were so close together in time and place, it has not been thought necessary to give separate returns for each experiment, but the returns from the several species will be considered separately.

RED SALMON

Of the 751 red salmon tagged, 308 were recaptured and reported. The returns are given in Table 2 and are shown graphically in Figure 1.

TABLE 2.—*Returns from red salmon tagged in the Cape Fox region, June 24 to July 1—761 tagged, 308 returned (40.8 per cent)*

Locality of recapture	Number	Time, in days
Chatham Strait:		
Between Hood Bay and Point Caution	1	36
Clarence Strait:		
Sealed Pass	1	11
Percy Islands	1	24
Bostwick Inlet	1	15
Vallenar Bay and Point	1	49
Streets Island	1	10
Nelson Cove	1	15
Clover Bay	1	24
Driest Point	1	17
Moira Sound	1	94
Ship Island	1	18
Behm Canal:		
Smeaton Bay	5	8–46
Roe Point	6	3–11
Sykes Point [1]	13	2– 9
Revillagigedo Channel:		
Carroll Inlet	2	21
Crab Bay	8	7– 8
Point Alava	1	36
Slate Island [1]	22	1–27
Boca de Quadra	49	1–45
Boca de Quadra hatchery	44	45–77
Revillagigedo Channel—Continued.		
Kah Shakes	16	1–66
Kirk Point	2	4– 8
De Long Island	3	6– 7
Foggy Point and Bay	14	2–14
Tree Point	31	2–21
Dixon Entrance:		
Cape Fox	3	22–42
Boat Rock	5	2– 9
Kanagunut Island	13	1–28
Garnet Point	6	11–18
British Columbia:		
Portland Inlet	1	5
Somerville Bay and Channel	4	0–28
Kutzeymateen Inlet	1	44
Nass River	35	2–69
Observatory Inlet	5	5–13
Wark Canal	1	44
Holland Rock	2	5–13
Tugwell Island	1	1
Skeena River	2	10–45
Kennedy Island	1	(?)
Edye Passage	1	41

[1] One recorded as taken before the date of tagging. Such cases are not considered in calculating the time elapsed between tagging and recapture.

By far the greater number of these fish went north and were taken in Revillagigedo Channel, Boca de Quadra, and Behm Canal. It is especially interesting to note the very large numbers taken in Boca de Quadra and at the Boca de Quadra hatchery. It is evident that this is one of the most important producing areas for the red-salmon runs that strike in at Cape Fox early in the season; and from the fact that so many of the tags were taken at the hatchery it seems possible that the hatchery operations are responsible for this unusual productiveness. In support of this we have the fact that the runs to the hatchery have been increasing for a number of

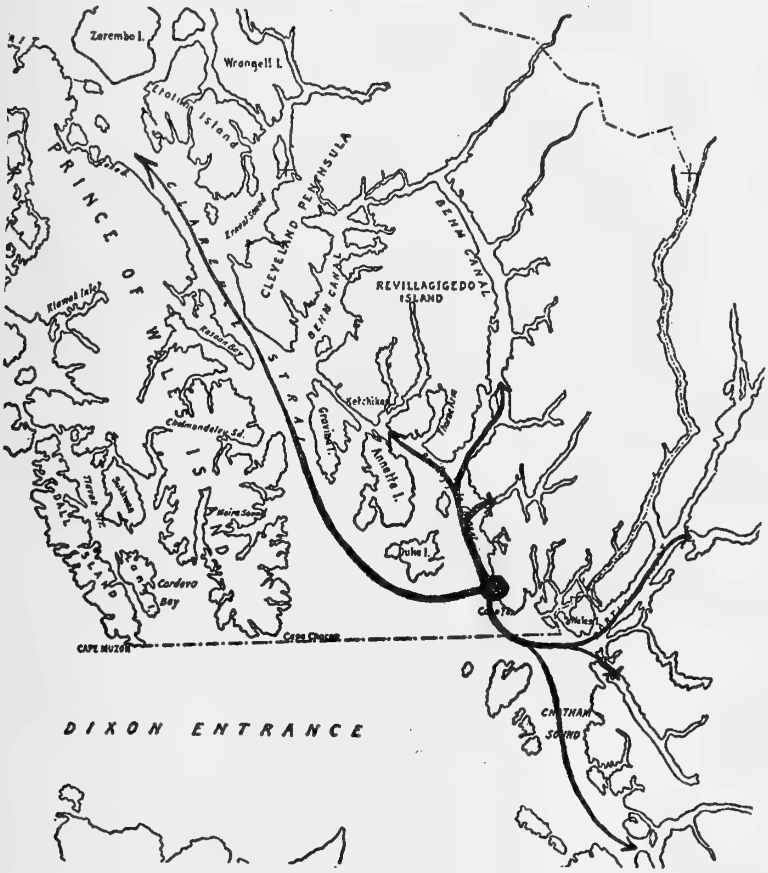

FIG. 1.—Distribution of red salmon tagged in Cape Fox region, June 24 to July 1, 1926. In this and the other similar figures the width of the lines indicating the routes of salmon migration show roughly the relative importance of each route

years. A smaller, though still important, component of the early run at Cape Fox is composed of red salmon derived from the Nass River. Forty-six tags were reported from the Nass and from the waters immediately adjacent and 35 of these were taken in the river itself. Eight others were taken elsewhere in British Columbia, including two taken in the Skeena River.

In the experiments of 1924 and 1925 the tagging in the Cape Fox region was done later in the season (July 30 to August 9), and but few red salmon were included, the total number being only 91. The recaptures numbered but 20, 10 of which came

from the region between Kanagunut Island and the mouth of Boca de Quadra. Other recaptures were made in both the Skeena and the Nass Rivers; and on the basis of these few data it was tentatively concluded that the Nass and Skeena Rivers are important sources of the red salmon found in the region about Cape Fox, at least during the latter part of the season. The experiments of 1926 support the theory that the Nass River, at least, is the source of an important part of the runs that pass Cape Fox, but show clearly (which the previous experiments did not) that a much more important element of the run has its origin in the streams to the north, and particularly in Boca de Quadra.

In a recent report [2] Williamson gives the results of the tagging of red salmon taken from traps at Haystack Island, British Columbia, just south of the international boundary, and only about 8 miles from Cape Fox. Between August 3 and 21, 1925, 659 sockeyes were tagged here. Of these 135 were recovered, 80 of which (60 per cent) were taken in the Nass River and 10 in Portland Canal and Observatory Inlet, waters immediately adjacent to the mouth of the Nass River. Thirteen were taken in the Skeena River, 5 in miscellaneous localities in British Columbia, and 27 in Alaskan waters. The Alaskan returns were mainly from the region of Cape Fox, Revillagigedo Channel, Clarence Strait, and Ernest Sound, the greatest number of returns from a single locality coming from Union Bay, Ernest Sound. A few were also retaken along the west coast of Prince of Wales Island.

Considering these experiments as a whole, both in Alaskan and in British Columbian waters, they indicate an interesting and significant segregation of the fish. Eighteen per cent of the recaptured fish tagged north of the international boundary had crossed over into Canadian waters, and 20 per cent of the returns from fish tagged south of the boundary were taken in Alaskan waters. The essential equality of these percentages is remarkable.

The experiments in Alaska have been carried on both early and late in the season and probably present a fairly accurate picture of the distribution of red salmon from the region of Cape Fox. The experiments in British Columbia are not quite so conclusive, however, inasmuch as they cover only the latter part of the season, and it would be extremely interesting and instructive if other experiments at Haystack Island could be made earlier in the year. In the light of our present knowledge, however, it appears that the red salmon that strike in through Dixon Entrance make with considerable directness for the streams of their origin. Those bound for Alaskan streams seldom swing south into the waters of British Columbia, and those bound for Canadian streams as rarely swing north and pass through Alaskan waters. This is, perhaps, the first recorded instance of fish respecting international boundaries!

COHOS

In the Cape Fox region 238 cohos were tagged between June 24 and July 1 and 41 were recaptured. The data are given in Table 3 and Figure 2.

[2] Pacific Salmon Migration: Report of the Tagging Operations in 1925. By H. Charles Williamson. Contributions to Canadian Biology and Fisheries, new series, Vol. III, No. 9, 1927.

TABLE 3.—*Returns from cohos tagged in the Cape Fox region, June 24 to July 1—238 tagged, 41 returned (17.2 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Clarence Strait:			Revillagigedo Channel—Continued.		
Cape Chacon	1	40	Kah Shakes	2	19–32
Bostwick Inlet	1	9	Tree Point	1	21
Streets Island	1	18	Dixon Entrance:		
Driest Point	2	17–31	Kanagunut Island	2	14–35
Dall Head	1	44	Garnet Point	1	23
Ship Island	2	35–40	British Columbia:		
Behm Canal:			Wales Island [1]	2	40–47
Roe Point	1	9	Nass River	1	4
Sykes Point	1	6	Wark Canal [1]	5	26–45
Revillagigedo Channel:			Zayas Island	1	14
North end Annette Island	2	65–78	Dundas Island	8	1–35
Slate Island	1	86	Skeena River	1	26
Mary Island	1	18	Smith Island	1	6
Club Rocks	1	9	Burke Channel	1	(?)

[1] One reported taken before the date of tagging.

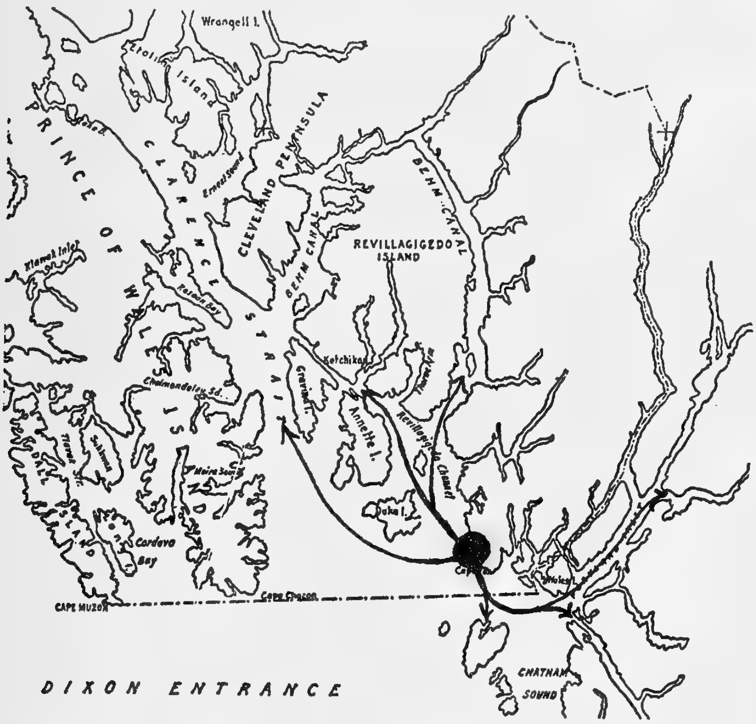

FIG. 2.—Distribution of cohos tagged in Cape Fox region, June 24 to July 1, 1926

The main migration routes are north into Revillagigedo Channel and Clarence Strait and south into various localities in British Columbia. Approximately one-half the total number returned were taken in British Columbia. In the experiments conducted late in July, 1925, only 79 cohos were tagged and 14 were returned, all from Alaskan waters. Although this can not be taken as conclusive evidence, it indicates that while approximately one-half of the earlier runs of cohos at Cape Fox originate in Canadian streams the later runs are, in large measure, if not exclusively, derived from streams in Alaska.

PINK SALMON

Twenty-six of 137 pink salmon tagged near Cape Fox in 1926 were recaptured. The data are given in Table 4 and graphically in Figure 3.

TABLE 4.—*Returns from pink salmon tagged in the Cape Fox region, June 24 to July 1—137 tagged 26 returned (19 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Clarence Strait:			Revillagigedo Channel—Continued.		
Percy Islands	2	30	Slate Island	1	11
Driest Point	1	13	Boca de Quadra [1]	4	13–19
Behm Canal:			Kirk Point	1	16
Roe Point	1	11	Foggy Point and Bay	2	7–9
Sykes Point	1	35	Tree Point	2	7–9
Revillagigedo Channel:			Dixon Entrance: Cape Fox	1	40
Point Higgins	1	39	British Columbia:		
Crab Bay	2	13–21	Steamer Passage	1	35
Lucky Cove	1	11	Nass River	1	55
Point Alava	3	13–35	China Hat Island	1	11

[1] One recorded as taken before the date of tagging.

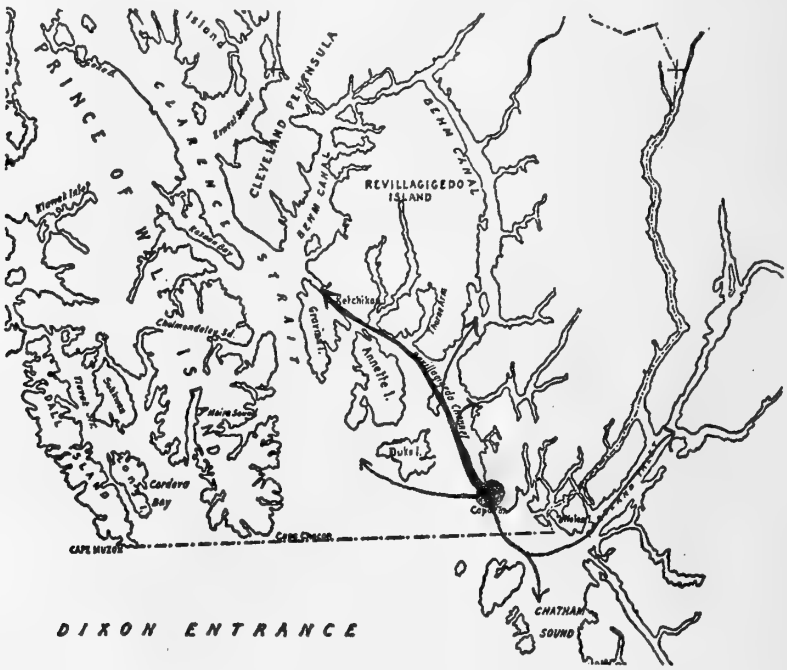

FIG. 3.—Distribution of pink salmon tagged in Cape Fox region, June 24 to July 1, 1926

These fish were taken chiefly in Revillagigedo Channel and contiguous waters, not far from the point of tagging. Only three (11.5 per cent) went south into British Columbia. The previous experiments of 1924 and 1925 came later in the season, when the run of pinks was at its height. As a result many more were tagged and retaken, but the general distribution was approximately the same. The percentages taken in the various localities vary considerably from year to year, but this is probably due (in part, at least) to the small number of fish tagged in 1926. No tagged pinks were taken in British Columbia in 1924, but 10.8 per cent of the recoveries of 1925 were taken there—approximately the same as in 1926.

CHUMS

At Cape Fox 358 chums were tagged, and 82 of these were retaken later. The data are given in Table 5 and Figure 4.

TABLE 5.—*Returns from chum salmon tagged in the Cape Fox region, June 24 to July 1—358 tagged, 82 returned (22.9 per cent)*

Locality of recapture	Number	Time, in days
Ernest Sound: Santa Anna	1	22
Clarence Strait:		
Dall Bay	2	10-38
Vallenar Bay	1	49
Streets Island	1	17
Nelson Cove	1	15
Ship Island	1	12
Behm Canal:		
Black Island	1	18
Roe Point	5	9-39
Point Caamaño	1	18
Sykes Point	5	5-52
Revillagigedo Channel:		
Carroll Inlet	1	20
Point Higgins	1	38
Lucky Cove	1	19
Slate Island	2	14-20
Boca de Quadra	15	9-20
Revillagigedo Channel—Continued.		
Boca de Quadra hatchery	2	40-61
Kah Shakes	4	5-26
Kirk Point	1	6
De Long Island	4	2-7
Foggy Point and Bay	9	3-44
Tree Point	9	1-12
Dixon Entrance:		
Cape Fox	1	22
Sitklan Island	1	28
Fillmore Inlet	1	16
Boat Rock	1	5
Kanagunut Island	2	7-14
Garnet Point	5	11-28
B tish Columbia:		
Sommerville Bay and Channel	1	20
Prince Rupert Cannery	1	27
Doubtful	1	

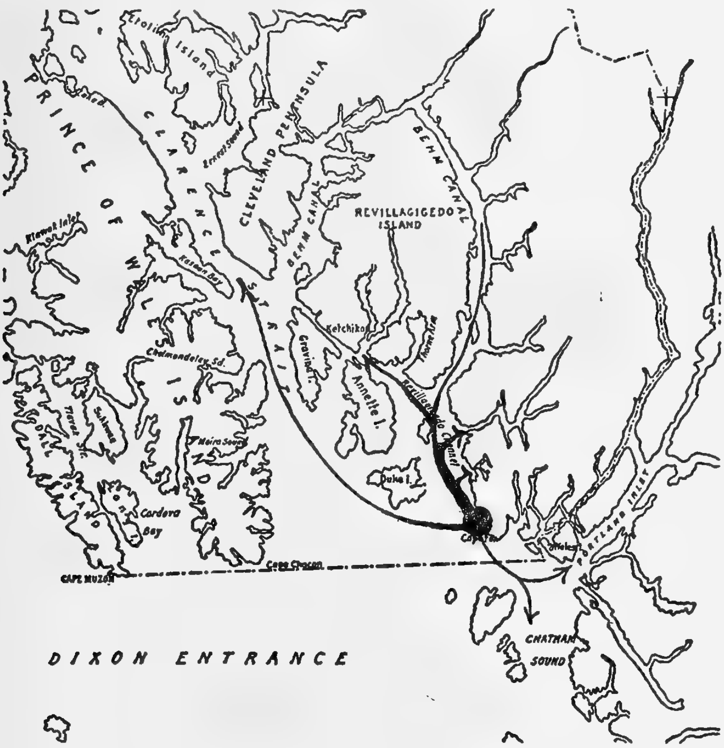

FIG. 4.—Distribution of chum salmon tagged in Cape Fox region, June 24 to July 1, 1926

By far the greater proportion of these fish were taken (as in the case of the pinks) in Revillagigedo Channel, Behm Canal, and Clarence Strait. Only three were taken in British Columbia. These results are, to all intents and purposes, identical with those obtained in 1924 and 1925.

RETURNS FROM EXPERIMENTS NEAR NELSON COVE, CLARENCE STRAIT

Tagging was done here on two days—July 6 and 7; 659 fish were tagged, of which 68 were reds, 116 cohos, 288 pinks, and 187 chums. There were no experiments in previous years that can be compared directly with these, but supplementary experiments are planned for future years.

RED SALMON

Sixty-eight were tagged but only 11 were recaptured and reported. The data for these are given in Table 6 and show a general distribution toward Ernest Sound and Revillagigedo Channel. One was taken near Cape Fox and another in British Columbia. The data are too few to be thoroughly reliable; but, so far as they go, they do not indicate that either the Boca de Quadra fish or the fish from the streams of British Columbia are found in any great numbers along the western coast of Gravina Island in the region of Nelson Cove.

TABLE 6.—*Returns from red salmon tagged near Nelson Cove, Clarence Strait, July 6 and 7, 1926—68 tagged, 11 returned (16.1 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Ernest Sound: Union Bay and Point	2	6-10	Revillagigedo Channel:		
Clarence Strait:			Slate Island	1	3
Meyers Island	1	11	Boca de Quadra hatchery	1	57
Nelson Cove	1	3	Dixon Entrance: Kanagunut Island	1	9
Driest Point	1	3	British Columbia: Humpback Bay, Porcher Island	1	3
Dall Head	1	11			
Clover Bay	1	23			

COHOS

The data for the cohos tagged near Nelson Cove are given in Table 7 and Figure 5. These show, as in the case of the red salmon, a distribution through Clarence Strait, Behm Canal, and Revillagigedo Channel, but indicate a distinctly heavier migration to the streams of northern British Columbia. Of 24 recaptured fish, 7 (30 per cent) were taken in Canadian waters, including both the Nass and the Skeena Rivers. This result is in accord with those from the experiments conducted in the region of Cape Fox and indicates a distinctly wider range of the cohos than of the other species tagged.

TABLE 7.—*Coho salmon tagged near Nelson Cove, Clarence Strait, July 6 and 7, 1926—116 tagged, 24 returned (20.6 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Chatham Strait: Point Gardner	1	59	Behm Canal—Continued.		
Clarence Strait:			Smeaton Bay	1	11
Cape Chacon	1	9	Revillagigedo Channel:		
Marsh Island	1	27	Point Alava	1	21
Skin Island	1	19	Kah Shakes Point	1	7
North end Gravina Island	1	7	Foggy Point and Bay	2	25-32
Duke Island	2	13-14	British Columbia:		
Dall Head	1	12	Nass River	1	(?)
Behm Canal:			Wark Canal	3	8-26
No details	1	30	Zayas Island	1	35
Bond Bay	2	7-10	Skeena River	2	22-51
Indian Point	1	25			

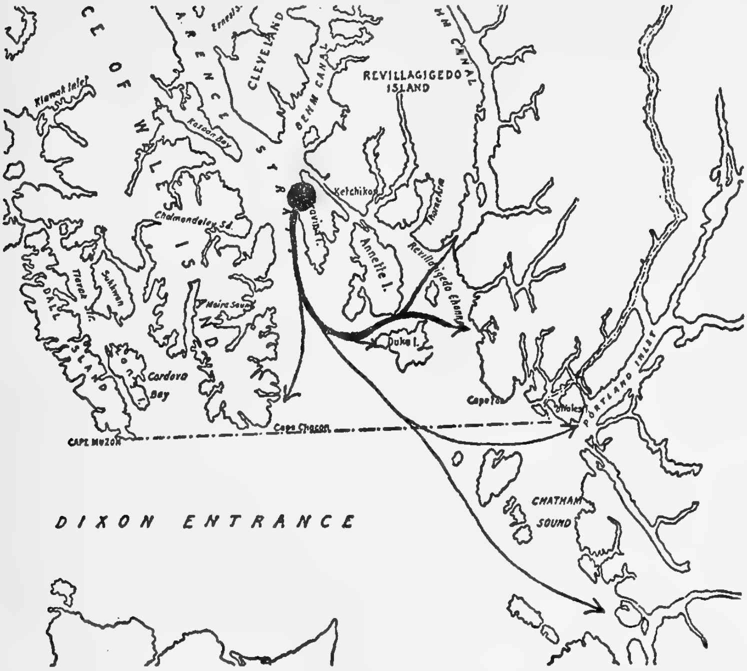

FIG. 5.—Distribution of cohos tagged near Nelson Cove, July 6 and 7, 1926

PINK SALMON

The data secured from the tagging of pink salmon in the region of Nelson Cove are given in Table 8 and Figure 6. With this species there has been no passing over into Canadian waters, and by far the greater part of the recovered fish were taken not far from the point where they were tagged—in Clarence Strait, Behm Canal, Revillagigedo Channel, and Ernest Sound. Two were reported taken near Cape Fox and two from localities in Stephens Passage.

TABLE 8.—*Pink salmon tagged near Nelson Cove, Clarence Strait, July 6 and 7—288 tagged, 68 returned (23.6 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Stephens Passage:			Behm Canal—Continued.		
Port Houghton	1	22	Betton Island	9	2–4
Windham Bay	1	21	Helm Bay	1	3
Clarence Strait:			Bond Bay	2	7–8
Moira Sound	1	10	Raymond Cove	1	3
Narrow Point	1	45	Caamaño Point	3	9–11
Percy Island	1	19	Ernest Sound:		
Driest Point	2	2–11	Point Eaton	2	4–10
Nelson Cove [1]	4	3	Point Warde	1	11
North end Gravina Island	2	3–4	Santa Anna	1	11
Smugglers Cove	1	3	Revillagigedo Channel:		
Meyers Island	4	3–7	Kah Shakes	1	19
Streets Island	4	5–14	Point Alava	2	35–37
Steamer Rock	1	18	Tree Point	2	5–9
Ship Island	1	3	Dog Island	1	40
Behm Canal:			Dixon Entrance: Cape Fox	2	29
Indian Point	11	2–5	Doubtful [2]	4	5–13
Roe Point	1	4			

[1] One reported taken before the date of tagging.

[2] From False Island, an unidentified locality.

Fig. 6.—Distribution of pink salmon tagged near Nelson Cove, July 6 and 7, 1926

CHUMS

One hundred and eighty-seven were tagged and 40 were recovered. As usual, the general distribution of the chums was much the same as that of the pinks—in great part to near-by localities. This local distribution of both pinks and chums

was a conspicuous feature of the results of the tagging done in 1924 and 1925. One chum salmon tagged at Nelson Cove was taken in the Nass River, British Columbia. The data are presented in Table 9 and Figure 7.

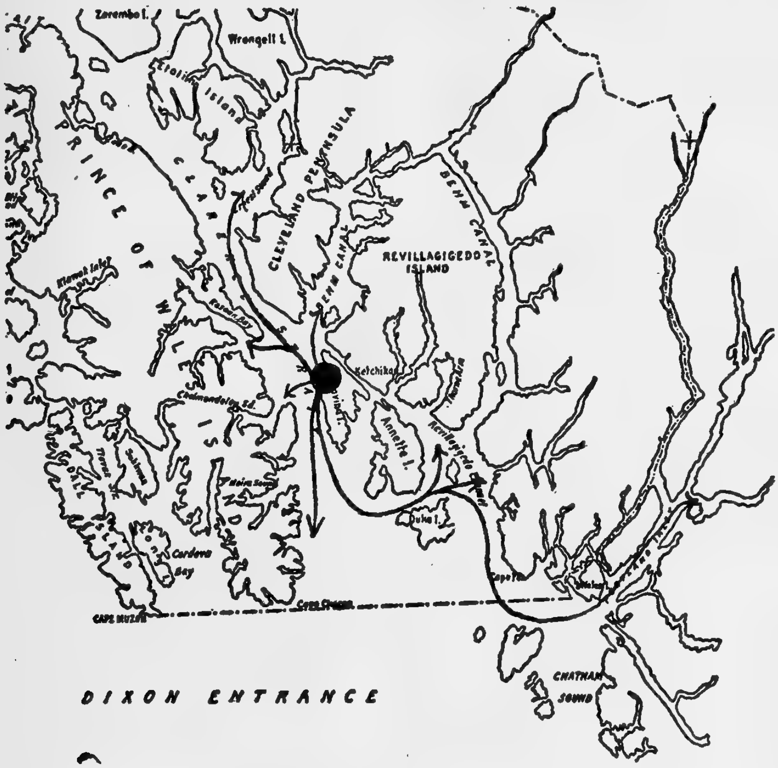

FIG. 7.—Distribution of chum salmon tagged near Nelson Cove, July 6 and 7, 1926

TABLE 9.—*Chum salmon tagged near Nelson Cove, Clarence Strait, July 6 and 7, 1926—187 tagged, 40 returned (21.4 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Ernest Sound:			Clarence Strait—Continued.		
Union Point	1	30	Ship Island	2	35-36
Vixen Inlet	1	27	Mosman Inlet	1	16
Santa Anna	1	22	Revillagigedo Channel:		
Seward Passage	1	23	Mountain Point	1	19
Point Eaton	1	36	Southwest shore of Revillagigedo Island	1	3
Point Warde	1	21	Point Sykes	2	11-26
Clarence Strait:			Boca de Quadra	1	6
Cape Chacon	1	38	Kah Shakes Point	1	40
McLeans Arm	1	30	Tree Point	1	9
Streets Island	1	20	Boat Rock	1	2
Skin Island	1	23	Behm Canal:		
Island Point—Prince of Wales Island	4	7-15	Bond Bay	1	4
Bostwick Inlet	1	22	Indian Point	1	5
Nelson Cove	1	2	Traitors Cove	1	23
Driest Point	1	15	Dixon Entrance: Kanagunut Island	1	4
North end Gravina Island	2	8-37	British Columbia: Nass River	1	6
Twelve Mile Arm	1	34	Doubtful	2	8-22
Meyers Chuck	2	23-37			

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RETURNS FROM EXPERIMENTS AT POINT COLPOYS, SUMNER STRAIT

Tagging was done at Point Colpoys on only one day—July 10—when 705 red salmon, 61 cohos, 259 pinks, and 11 chums were tagged. Only eight of the tagged cohos were recaptured; one of these was taken at Point Colpoys six days after being tagged, and the others were captured south of Point Colpoys, between Screen Islands and Foggy Bay, in the waters of Clarence Strait, Ernest Sound, Behm Canal, and Revillagigedo Channel. Only one of the chums was recaptured; this was taken eight days after being tagged at Marsh Island, near the northern end of Clarence Strait.

RED SALMON

One hundred and thirty-four red salmon tagged were retaken. The data are given in Table 10 and are shown graphically in Figure 8.

TABLE 10.—*Red salmon tagged at Point Colpoys, July 10, 1926—705 tagged, 134 returned (19 per cent)*

Locality of recapture	Number	Time, in days
Stephens Passage: Hobart Bay	1	12
Frederick Sound:		
Deepwater Point	4	10–12
Carroll Island	1	31
Wrangell district:		
Dry Strait	1	14
Stikine Flats [1]	2	16
Concks Creek	2	12–19
Chichagof Pass	8	3–14
Sumner Strait:		
Red Bay	1	11
Point Colpoys	4	6
Point McNamara	2	9
Snow Passage	2	6–19
Point Nesbitt	4	4–6
Clarence Strait:		
Marsh Island	3	8–9
Screen Islands	5	4–9
Lincoln Rock	4	6
Eagle Creek	11	4–6
Coffman Island	7	5–11
Point Stanhope	2	8
McHenry Inlet	3	12
Kelp Point	2	4–11
Meyers Island	1	4
Meyers Chuck	1	13
Point Niblack	1	18
Streets Island	8	0–10
Narrow Point	5	8–42
Lyman Anchorage	1	22
Kasaan Point	1	21
Grendall Island	8	5–10
Clarence Strait—Continued.		
Clover Bay	2	8–11
Skin Island	1	15
Halibut Creek	1	9
Island Point (Prince of Wales Island)	1	7
Point Adams	1	12
Point Caamaño	2	6–7
North end Gravina Island	1	21
West shore Gravina Island	1	37
Nelson Cove	1	9
Dall Head	1	6
Crab Bay	1	5
Duke Island	2	24
Ernest Sound:		
Union Point	1	2
Emerald Bay	1	16
Point Eaton	2	4–15
Brownson Island	1	4
Frosty Bay	1	16
Anan	1	12
Behm Canal:		
Betton Island	1	6
Fortman hatchery	1	85
Revillagigedo Channel:		
Mountain Point	1	11
Carroll Point	2	9–39
Point Alava	1	18
Kah Shakes	1	14
Foggy Bay	2	5–16
British Columbia: Observatory Inlet	2	10–13
Doubtful	6	6–13

[1] One reported taken before date of tagging.

A slight migration northward into the Stikine district and Stephens Passage is indicated, but the main line of distribution is southward through Clarence Strait, Ernest Sound, Behm Canal, and Revillagigedo Channel. Only two were recorded as taken in British Columbia. In 1924 and 1925 a number of experiments were conducted at Ruins Point; also in Sumner Strait, though west and south of Point Colpoys about 40 miles. In 1924 the tagging at Ruins Point was scattered over a number of days between July 12 and August 17, and in 1925 it was done between July 18 and 25. There is very little difference in the distribution of the red salmon tagged at Ruins Point in 1924 and 1925 and at Point Colpoys in 1926, except such as would naturally follow as a result of the migration in through Sumner Strait. A few

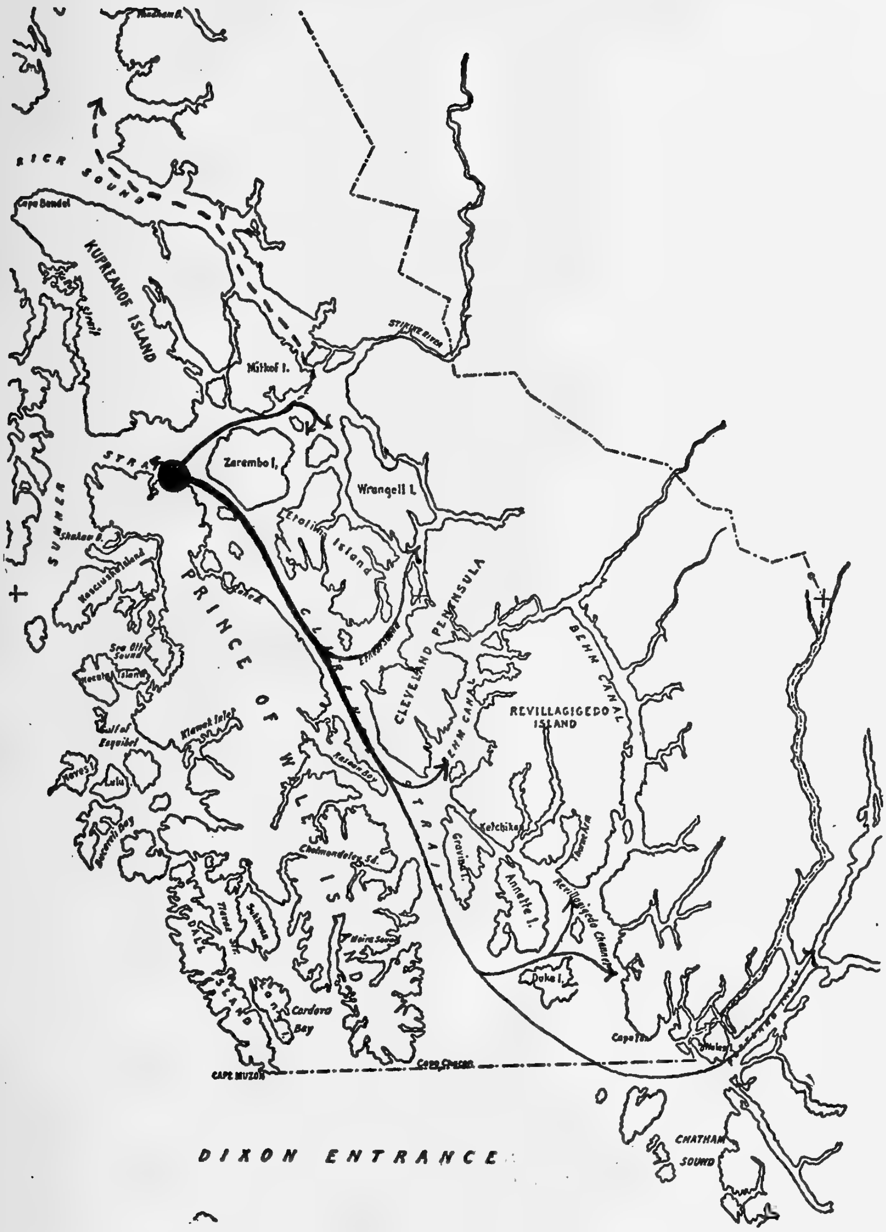

FIG. 8.—Distribution of red salmon tagged at Point Colpoys, July 10, 1926

of the fish tagged at Ruins Point went out of Sumner Strait again and were taken in the lower part of Chatham Strait and along the western coast of Prince of Wales Island; but the main route of migration was north and east through Sumner Strait and then south through Clarence Strait to Ernest Sound, Behm Canal, and Revillagigedo Channel, just as occurred in 1926 with the red salmon tagged at Point Colpoys. In the previous years a few reds were taken in the Stikine district and a few in British Columbia, just as in 1926. Of the returns taken in British Columbia, the greatest number was the result of the 1924 tagging. In that year 9 out of a total of 56 returns were taken in the Skeena River. It seems probable that this was due merely to chance fluctuations in the percentages of Skeena River fish among those tagged in the various experiments, inasmuch as no such results were obtained in either 1925 or 1926, when many more fish were tagged. It may be, however, that a greater number of Skeena River fish pass through Sumner Strait in some years than in others.

PINK SALMON

Sixty-eight pink salmon, tagged at Point Colpoys, were recovered, and the data are given in Table 11 and Figure 9.

TABLE 11.—*Pink salmon tagged at Point Colpoys, July 10, 1926—259 tagged, 68 returned (26.2 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Frederick Sound:			Clarence Strait—Continued.		
Herring Bay	1	13	Halibut Creek	1	8
Deepwater Point	1	12	Bostwick Inlet	1	14
Wrangell District:			Driest Point	1	7
Stikine River	2	3	Crab Bay	1	8
Chichagof Pass	1	14	Ernest Sound:		
Sumner Strait: Point Nesbitt	1	9	Union Point	1	12
Clarence Strait:			Point Eaton	8	4–5
Coffman Island	1	5	Brownson Island	6	4–13
Steamer Bay	1	12	Santa Anna	3	5–19
Screen Islands	1	4	Point Warde	3	4–7
Lincoln Rock	1	9	Point Watkins	2	0
Steamer Rock	2	5–14	Anan	4	8–15
Eagle Creek	1	5	Bradfield Canal	1	12
Onslow Island	1	34	Behm Canal:		
Kelp Point	1	1	Betton Island [1]	2	4
Meyers Island	4	4	Grant Island	1	14
Streets Island	1	8	Indian Point	1	5
Northwest Cove	5	6–10	Revillagigedo Channel: Boat Rock	1	16
Grindall Island	1	10	Doubtful	5	1–13

[1] One recorded as taken before date of tagging.

The distribution of pinks was much the same as that of the red salmon—that is, to Clarence Strait, Ernest Sound, Behm Canal, and Revillagigedo Channel. These results were the same as those secured in 1924 and 1925 from the tagging at Ruins Point, except for the fact, which would naturally be expected, that in the earlier experiments a considerable proportion of the returns came from the west coast of Prince of Wales Island, in Chatham Strait, north of the entrance to Sumner Strait, and in Sumner Strait west and south of Point Colpoys.

RETURNS FROM EXPERIMENTS AT CAPE BENDEL, FREDERICK SOUND

At this point, 3,297 salmon were tagged between July 15 and 18. Fourteen were red salmon, 7 were cohos, 3,177 pinks, and 99 were chums. None of the cohos was recovered and only four of the red salmon. Two of these came from Snettisham

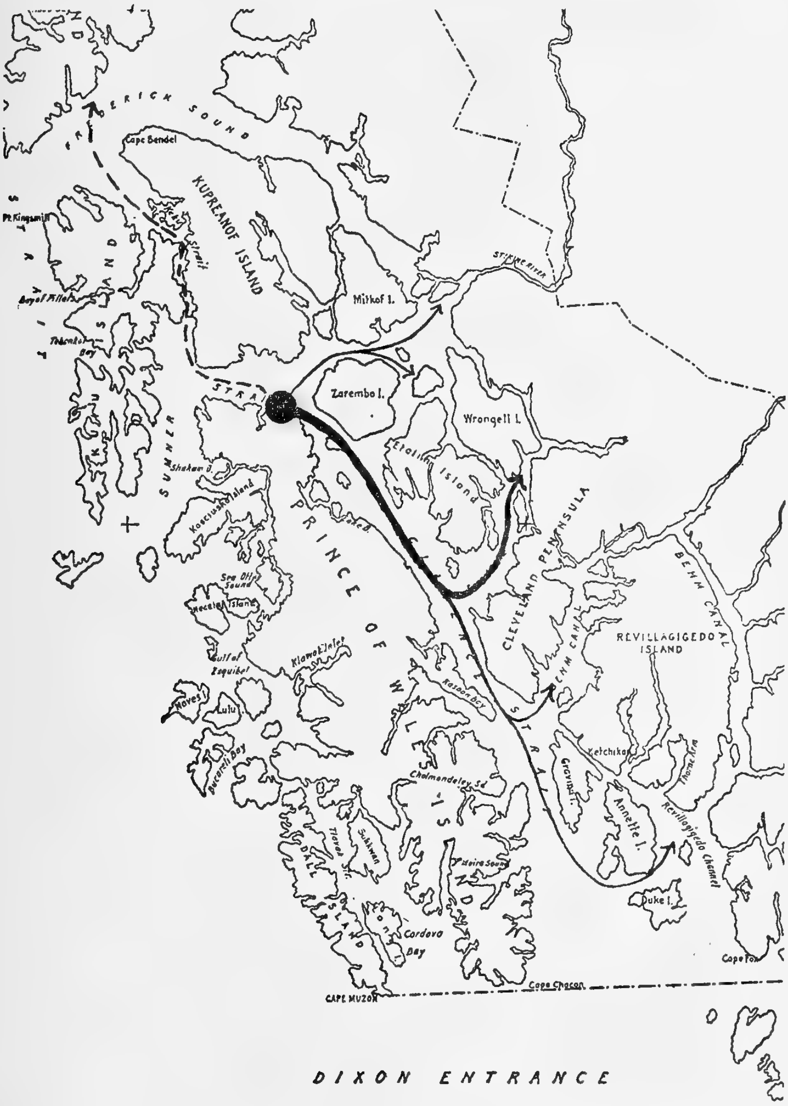

FIG. 9.—Distribution of pink salmon tagged at Point Colpoys, July 10, 1926

Inlet, Stephens Passage; one from Deepwater Point, Frederick Sound; and one from Cape Bendel. So far as these few returns go, they indicate a migration similar to that of the reds tagged in previous years at Kingsmill Point, in Chatham Strait, just below the entrance to Frederick Sound.

PINK SALMON

Of the pink salmon tagged, 1,093 were recovered and the data are presented in Table 12 and Figure 10.

TABLE 12.—*Pink salmon tagged at Cape Bendel, July 15 to 18, 1926—3,177 tagged, 1,093 returned (34.5 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Icy Strait:			Frederick Sound and Keku Strait—Con.		
No details	8	12–21	Pybus Bay, Point, and Reef	116	0–26
Point Adolphus	1	4	Wilson Cove	5	7–21
Chatham Strait, north of Frederick Sound:			Deepwater Point	79	2–18
Hawk Inlet	3	9–17	Cape Fanshaw	115	1–25
Point Marsden	1	14	Bay Point	5	1–23
South Passage Point	1	7	Highland Point	26	6–24
Marble Bluffs	3	11–19	Farragut Bay	7	2–7
Basket Bay	9	6–21	Cape Strait	42	4–25
Rocky Bay, Point Thatcher	3	12–22	Twelve Mile Creek	3	13–32
Kelp Bay	2	14–16	Five Mile Creek	1	22
Hood Bay	4	21–27	Dry Strait	2	5–7
Between Hood Bay and Point Caution	13	5–15	No details [2]	9	
Chatham Strait, south of Frederick Sound:			Stephens Passage:		
Security Bay	3	4–9	Port Houghton [3]	70	3–24
Washington Bay	3	6–11	Hobart Point	27	2–26
Tebenkof Bay	4	5–31	Hobart Bay	15	0–10
South of Kingsmill Point	2	4–7	Gambier Bay	11	7–24
Frederick Sound and Keku Strait:			Sunset Island	18	6–24
Kingsmill Point	1	7	Windham Bay	141	2–22
Hourigan Point	1	9	Dry Bay	15	4–37
Saginaw Bay	14	5–19	Hugh Point	1	7
Keku Island	7	1–4	Seymour Canal [4]	65	0–26
Keku Strait	1	26	Snettisham Inlet	1	7
Kadake Bay	2	8–9	Limestone Inlet	21	4–19
Point Camden	1	8	Taku Inlet	3	14–19
Hamilton Bay	1	13	Salmon Creek, Juneau	2	37–39
Kake	2	13–14	Shoal Point	1	12
Point McCartney [1]	21	0–13	Stikine River [4]	6	
Cape Bendel	104	1–26	Sumner Strait, McNamara Point	2	4
Herring Bay	45	2–23	Behm Canal, Chickamin River	1	20
Elizar Harbor	7	1–17	Clarence Strait, Cape Chacon	2	24–29
Napean Point	5	3–9	Doubtful	1	16
Carroll Island	8	3–16			

[1] One reported taken before the date of tagging.
[2] All reported taken between July 15 and Aug. 1.
[3] Three reported taken before date of tagging.
[4] Four reported taken before date of tagging.

About 5 per cent of the fish went to the westward from Cape Bendel and were taken in Chatham Strait, both north and south of Frederick Sound, and a few went as far north as Icy Strait. The great majority of the fish, however, were taken in the region of Frederick Sound and Stephens Passage. On August 4, 1924, nearly 600 pink salmon were tagged near Cape Bendel. The distribution of these fish was virtually the same as of the fish tagged in 1926, although a somewhat larger proportion was taken in Chatham Strait, south of Frederick Sound, and in Sumner Strait. The differences in the percentages do not appear to be significant, and the main lines of migration are undoubtedly the same. In the case of the pinks tagged at Kingsmill Point in 1924 and 1925, the general distribution is again the same as with those tagged at Cape Bendel in 1926, except that, as would be expected, considerable numbers were taken in Chatham Strait near Kingsmill Point and in Frederick Sound west of Cape Bendel. A larger percentage of the fish tagged at Point Kingsmill, also, was taken in Sumner Strait.

CHUMS

Twenty-one chums were recaptured and reported; all but one (which was taken in Chatham Strait) came from Frederick Sound and Stephens Passage. The data are given in Table 13. The previous experiments, both at Cape Bendel and Point

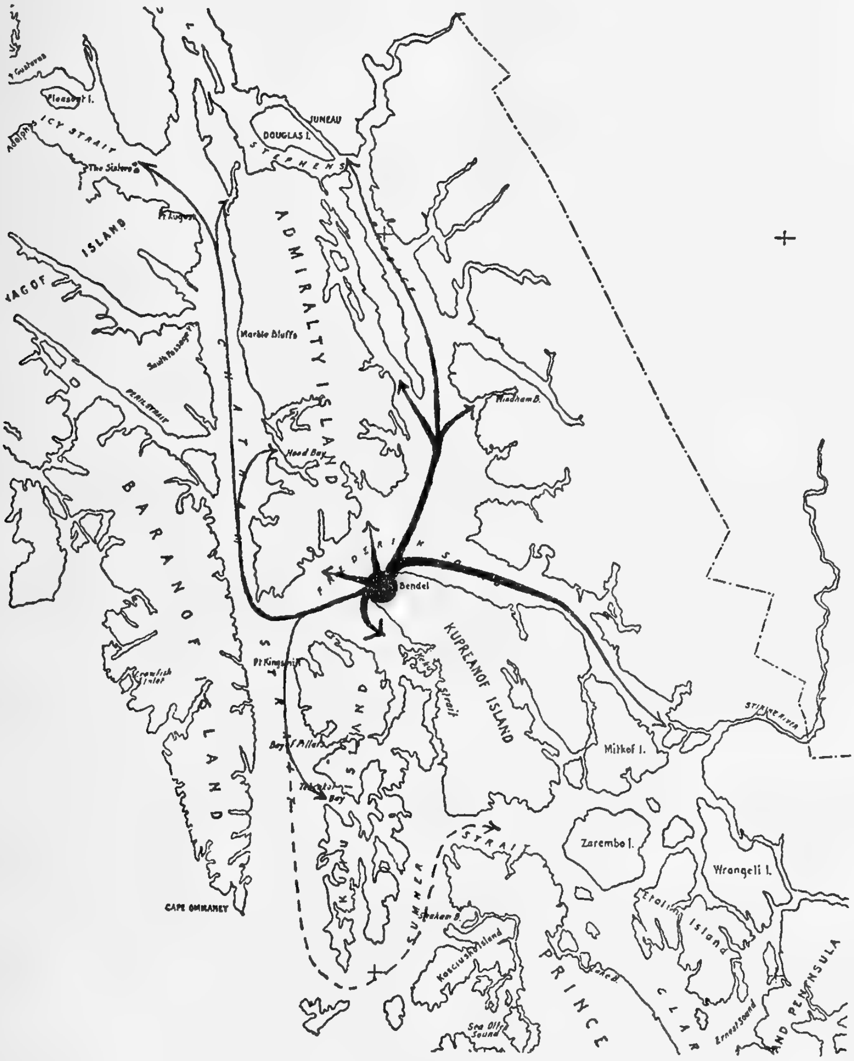

FIG. 10.—Distribution of pink salmon tagged at Cape Bendel, July 15 to 18, 1926

Kingsmill, indicated a similar local distribution of the fish entering Frederick Sound, although in the case of the experiments at Point Kingsmill there was a more important migration south into the numerous bays of the west coast of Kuiu Island.

TABLE 13.—*Chum salmon tagged at Cape Bendel, July 15 to 18, 1926—99 tagged, 21 returned (21.2 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Chatham Strait: No details	1	18	Stephens Passage:		
Frederick Sound:			Port Houghton	1	14
Point Camden	1	26	Dry Bay	1	17
Point Napean	1	10	Windham Bay	1	5
Deepwater Point	3	3–7	Sunset Island	1	11
Pybus Bay	5	2–17	Seymour Canal	2	5–7
Point Highland	2	6–8	Shelter Cove	1	6
Farragut Bay	1	4			

RETURNS FROM EXPERIMENTS AT PARKER POINT, CHATHAM STRAIT

At Parker Point, between July 20 and 22, 999 salmon were tagged; 47 were red salmon, 3 cohos, 927 pinks, and 22 chums. None of the cohos was recaptured and but one of the chums. That one was taken at Marble Bluffs one day after the tagging. None of the previous experiments can be compared directly with the one under discussion.

RED SALMON

Seventeen of the red salmon tagged at Parker Point were returned, and the data are given in Table 14.

TABLE 14.—*Red salmon tagged at Parker Point, Chatham Strait, July 20 to 22, 1926—47 tagged, 17 returned (36.2 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Icy Strait: No details	1	9	Frederick Sound: Pybus Bay	1	8
Chatham Strait:			Stephens Passage:		
No details	2	40–46	Windham Bay	1	6
Funter Bay	2	3–4	Taku Inlet	4	4–16
Hawk Inlet	1	(1)	Outer Point, Douglas Island	1	4
Marble Bluffs	1	1			
Rocky Bay	1	2			
Basket Bay	2	3			

[1] Reported taken before date of tagging.

Although the data are too few to form a basis for more than tentative conclusions, they indicate a migration both north and south of the point where the tagging was done. Red salmon were taken in Chatham Strait north of the point of tagging, as far as Funter Bay and also in Icy Strait. Others were taken in Chatham Strait, south of Parker Point, and in Frederick Sound. It is a question as to which route was taken by the fish that were recaptured in Stephens Passage. They might have gone through Frederick Sound or around the northern end of Admiralty Island. It seems rather probable that the latter course was taken, inasmuch as other experiments, to be described later, show a distinct migration of red salmon from Icy Strait around the northern end of Admiralty Island, to Taku Inlet.

PINK SALMON

The data on the pink salmon tagged at Parker Point are given in Table 15 and Figure 11. The distribution is unusually wide for pink salmon, showing a fairly well-marked migration north in Chatham Strait and into Icy Strait, and a more important

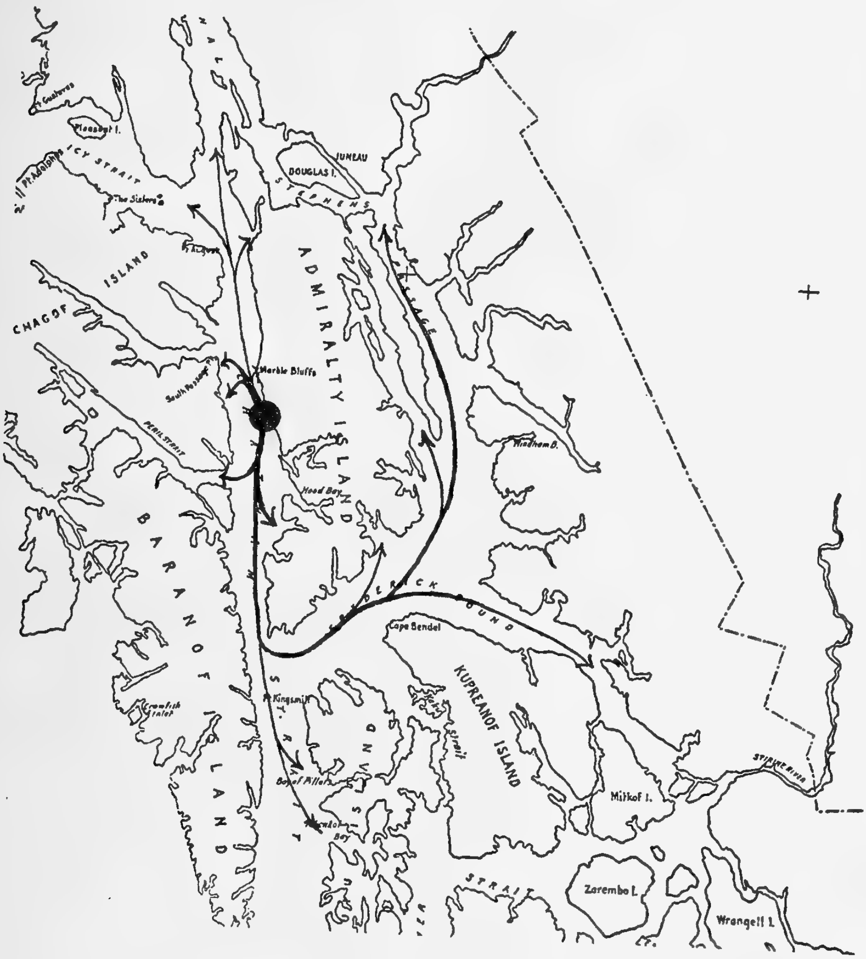

FIG. 11.—Distribution of pink salmon tagged at Parker Point, July 20 to 22, 1926

migration into Frederick Sound and Stephens Passage. Others were taken in Peril Strait, Slocum Arm (on the outer coast of Chichagof Island), Clarence Strait, and one was recaptured in the Nass River, British Columbia.

TABLE 15.—*Pink salmon tagged at Parker Point, Chatham Strait, July 20 to 22, 1926—927 tagged, 321 returned (34.6 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Icy Strait:			Slocum Arm	7	8-16
No details	8	8-15	Frederick Sound:		
Point Adolphus	1	9	Herring Bay	9	3-20
Spasskaia Bay	2	9-10	Napean Point	2	2-5
Rocky Islet	3	3-7	Murder Cove	1	7
Chatham Strait (north of Parker Point):			Deepwater Point	6	4-10
False Point Retreat	4	7-20	Carroll Island	4	2-6
Funter Bay	5	3-13	Pybus Bay, Point, and Reef	13	5-16
Hawk Inlet [1]	10	3-16	Keku Island [1]	1	(?)
Kelp Bay	4	4-11	Kadake Bay	1	6
Freshwater Bay	1	39	Hamilton Bay	1	22
Fishery Point	4	1-14	Point McCartney	1	20
South Passage Point	4	3-11	Cape Bendel	4	4-16
Tenakee	1	33	Cape Fanshaw	5	3-19
Basket Bay	30	2-20	Highland Point	1	6
Marble Bluffs [1]	46	1-17	Cape Strait	2	0-4
Parker Point	6	2-19	Twelve Mile Creek	1	26
No details	1	10	Stephens Passage:		
Chatham Strait (south of Parker Point):			Port Houghton	8	2-17
Favorite Bay [2]	2	47	Hobart Point	1	13
Morris Reef	8	3-15	Gambier Bay	1	29
Rocky Bay	15	2-14	Windham Bay	7	6-17
Hood Bay	5	14-20	Sunset Island [1]	3	18-19
Chaik Bay	1	44	Seymour Canal	7	7-14
Wilson Cove	4	2-5	Limestone Inlet	8	10-17
Between Hood Bay and Point Caution	35	1-11	Shelter Cove	3	2-3
Washington Bay	2	6-7	Outer Point	5	2-6
Tebenkof Bay	3	14-25	Clarence Strait: Driest Point	1	13
Peril Strait:			British Columbia: Nass River	1	59
No details	1	17	Doubtful	10	1-8
Rodman Bay	1	0			

[1] One reported taken before the date of tagging.
[2] One with date of capture unknown.

RETURNS FROM EXPERIMENTS IN ICY STRAIT

The experiments in the Icy Strait region were all conducted near the Inian Islands at the extreme eastern end of the strait. Two thousand salmon were tagged, of which 127 were reds, 47 cohos, 1,804 pinks, and 21 chums. Five of the cohos were retaken—one near Pleasant Island, Icy Strait, in 3 days; another near Lemesurier Island, Icy Strait, in 6 days; another at Danger Point, Chatham Strait, in 26 days; another at Fishery Point, Chatham Strait, in 15 days; and one in Peril Strait, in 12 days. Two of the chums were returned, one from Point Adolphus in 7 days and the other from False Bay on Chichagof Island, Chatham Strait. This last record was faulty, the date of capture as given being before the date of tagging.

RED SALMON

Thirty-four red salmon were recaptured. The data are given in Table 16 and the distribution is shown graphically in Figure 12.

TABLE 16.—*Red salmon tagged in Icy Strait district, July 24 to 29, 1926—127 tagged, 34 returned (26.8 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Icy Strait:			Slocum Arm	3	4-7
No details	1	4	Chatham Strait:		
Cape Spencer	1	1	No details	4	3-11
Port Althorp	1	(1)	Hawk Inlet	1	7
Inian Cove	1	6	Frederick Sound, Cape Bendel	1	12
Eagle Point	2	3-9	Stephens Passage:		
Gull Cove	5	2-6	Shoal Point	1	6
Dundas Bay	1	7	Taku Inlet	3	1(?)-8
Point Adolphus	3	3-7	No information	1	(?)
Pleasant Island	3	2-8			
Excursion Inlet	2	4-8			
Porpoise Island	1	7			

[1] Reported taken before tagged.

A few of these fish went westward and were taken in Cross Sound and Slocum Arm. The main route of migration, however, was to the eastward through Icy Strait and thence, apparently, around the northern end of Admiralty Island to Stephens Passage and Taku Inlet. Only a small component goes south through Chatham Strait to Frederick Sound. The experiments at Douglas Island (to be described later) corroborate the results of these in Icy Strait and show that an important migration of reds passes Douglas Island on the way to Taku Inlet. These

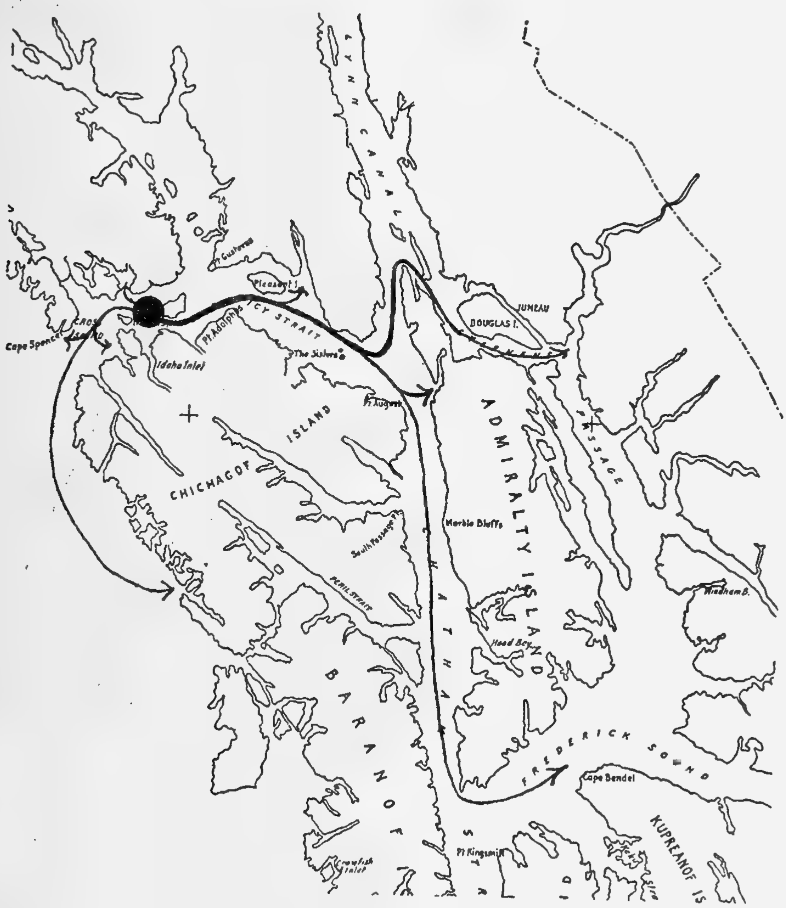

FIG. 12.—Distribution of red salmon tagged in Icy Strait, July 24 to 29, 1926

results are strikingly different from those of the previous experiments. The tagging of 1924 and 1925 was done early in the summer, mainly between June 23 and July 1, and, therefore, tested the migration of the early part of the run only. A larger proportion of these early fish went south in Chatham Strait to Frederick Sound; none were taken in Stephens Passage, but there was a well-marked migration into Lynn Canal, where the Chilkat and Chilkoot Rivers are. These are known to be the sources of important runs of red salmon, and from these experiments it is evident that the reds bound for these two rivers enter Icy Strait early in the season.

Later in the season the Chilkat and Chilkoot fish disappear from the red-salmon runs that enter Icy Strait, and they are succeeded by an important component derived from the Taku River. All through the season some of the Icy Strait fish pass south through Chatham Strait and are presumably distributed to local spawning grounds tributary to Chatham Strait and Frederick Sound.

PINK SALMON

Of 1,804 pink salmon tagged, 616 were returned. The main route of migration was east through Icy Strait, thence south through Chatham Strait to Frederick Sound. Very few were recaptured outside of these waters; 11 were taken at Shoal

FIG. 13.—Distribution of pink salmon tagged in Icy Strait, July 24 to 29, 1926

Point, on Douglas Island, and others in Chatham Strait, north of Icy Strait. These indicate a slight migration into Stephens Passage around the northern end of Admiralty Island. The results agree perfectly with those secured from the previous

experiments, and it may be concluded that there is no great difference in the distribution of pink salmon that enter Icy Strait at various times during the season. The data are given in Table 17 and Figure 13.

TABLE 17.—*Pink salmon tagged in Icy Strait, July 24 to 29, 1926—1,804 tagged, 616 returned (34.0 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Icy Strait and Cross Sound:			Chatham Strait—Continued.		
No details	16	4–13	South Passage Point	4	5–11
Cape Spencer	1	2	Marble Bluffs	29	3–16
Inian Island [1]	19	0–9	Basket Bay	23	6–16
Inian Cove	8	0–4	Parker Point [4]	1	(?)
Lisianski Island and Inlet	1	5	Sitkoh Bay	1	1
Stag Bay [2]	5	2–14	Morris Reef	5	7–12
George Island	7	3–5	Rocky Bay	6	6–14
Port Althorp [3]	28	0–11	Hood Bay	7	6–17
Gull Cove	27	2–12	Between Hood Bay and Point Caution	6	6–17
Eagle Point	11	3–11	Village Point, Chaik Bay	1	7
Dundas Bay	1	4	Wilson Cove	3	6–14
Dundas Point [1]	7	2–14	Peril Strait: No details	2	2–12
Mud Bay	1	4	Chatham Strait, south of Frederick Sound:		
Division Point	1	6	South of Kingsmill Point	1	12
Lemesurier Island	14	2–14	Washington Bay	1	19
Point Gustavus	16	3–9	Tebenkof Bay	3	15–21
Point Adolphus	57	2–12	Frederick Sound:		
Pleasant Island	29	4–11	Keku Strait	1	20
Excursion Inlet	19	4–37	Point McCartney [5]	1	0
Pinta Cove	6	1–7	Cape Bendel	2	4–12
Spasskaia Bay	9	3–11	Herring Bay	8	9–14
Porpoise Island	18	1–9	Eliza Harbor	1	11
Point Sophia	1	6	Carroll Island	1	8
Rocky Point	7	4–12	Murder Cove [4]	1	8
Rocky Islet	13	2–9	Pybus Bay	10	6–18
Point Augusta	3	6–7	Stephens Passage:		
Slocum Arm	4	7–11	Gambier Bay	2	7–16
Chatham Strait, north of Frederick Sound:			Windham Bay	1	15
No details	39	1–12	Seymour Canal	6	5–9
False Point Retreat	1	12	Limestone Inlet	3	5–11
Funter Bay	12	2–8	Groundhog Bay	1	3
Young Island [4]	1	(?)	Shoal Point	11	6–10
Hawk Inlet	52	2–13	Stikine River	1	19
Point Marsden	5	2–5	Ernest Sound: Meyers Chuck	1	17
False Bay	11	2–11	Clarence Strait: Cape Chacon	1	18
Tenekee	1	20	British Columbia: Nass River	1	88
Fishery Point	13	5–12	Doubtful	6	5–7

[1] One without record of date captured.
[2] One reported taken before date of tagging, and one without record of date captured.
[3] Nineteen reported taken before date of tagging, and one without record of date captured.
[4] One reported taken before date of tagging.
[5] Doubtless an error in the time record.

RETURNS FROM EXPERIMENTS AT DOUGLAS ISLAND, STEPHENS PASSAGE

RED SALMON

The data bearing on the red salmon tagged near Douglas Island are given in Table 18 and are shown graphically in Figure 14. Five hundred and sixteen were tagged and 215 recaptured. A striking feature is the great predominance of the returns from Taku Inlet. Over 85 per cent of all the returns came from this locality and from the Taku River, and others came from points between where the fish were tagged and the entrance to Taku Inlet. Most of the other returns came from various localities in Stephens Passage.

TABLE 18.—*Red salmon tagged near Douglas Island, Stephens Passage, July 31 to August 3, 1926—516 tagged, 215 returned (41.6 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
Icy Strait, Spasskaia Bay	1	(1)	Stephens Passage—Continued.		
Chatham Strait, Fishery Point	1	6	Auke Bay	1	20
Frederick Sound, Cape Bendel	1	4	Seymour Canal	1	4
Stephens Passage:			Limestone Inlet	11	3–6
Shoal Point	11	1–5	Point Hobart	1	7
Douglas Island	1	6	British Columbia, Shelsey River (Taku system)	3	34–51
Taku Inlet [2]	173	0–6	Doubtful	3	
Taku River, Taku Point	7	0–4			

[1] Reported taken before date of tagging.

[2] Seven reported taken before date tagged.

FIG. 14.—Distribution of red salmon tagged at Douglas Island, July 31 to August 3, 1926

CHUMS

Ninety-nine chums were tagged between July 31 and August 3. Only four were recaptured, one each from the following localities: Limestone Inlet, 5 days; Salmon Creek, Juneau, 29 days; Glass Peninsula, 9 days; Spasskaia Bay, Icy Strait, date of capture doubtful.

COHOS

Ninety were tagged and 15 recaptured. Ten of these were taken in Taku Inlet in from 2 to 5 days after being tagged. One was reported taken at each of the following localities: Middle Point, Douglas Island, in 44 days; Hood Bay, 4 days; Marble Bluffs, 3 days; Limestone Inlet, 3 days; and Seymour Canal, 5 days.

PINK SALMON

Of 794 pink salmon tagged at Douglas Island, 181 were retaken. The data are given in Table 19 and Figure 15. The distribution was primarily to waters tributary

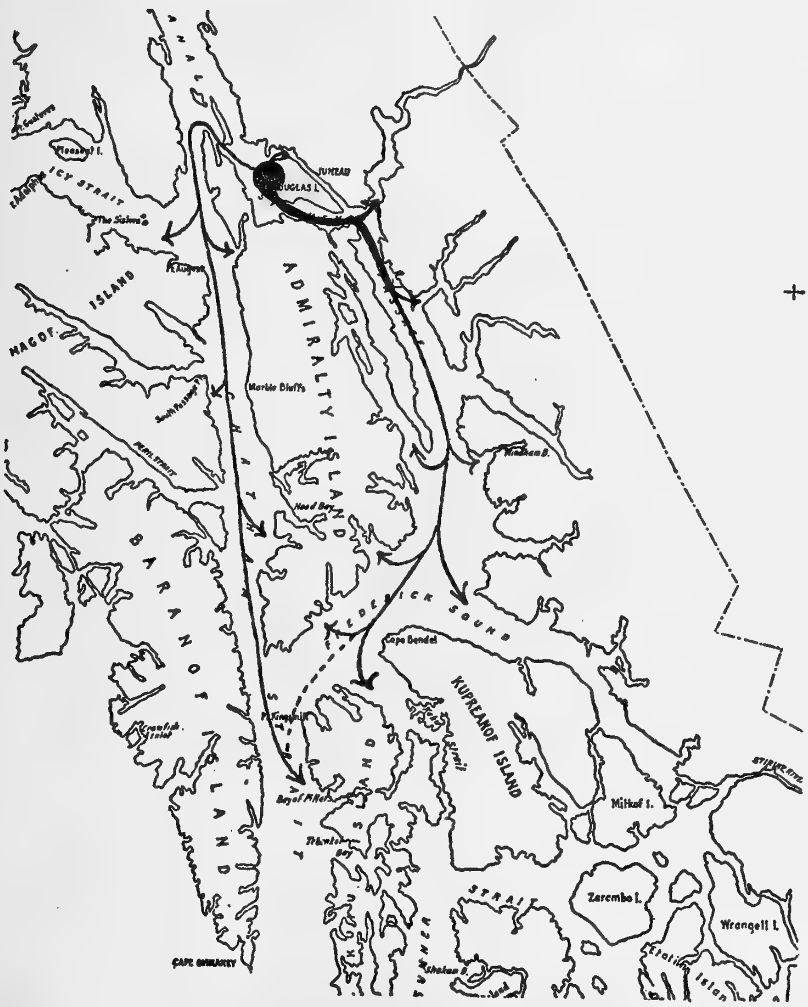

FIG. 15.—Distribution of pink salmon tagged at Douglas Island, July 31 to August 3, 1926

to Stephens Passage, but there is evidently a well-marked movement into Chatham Strait, probably around the northern end of Admiralty Island. Those taken in Frederick Sound may have reached there through Stephens Passage or through Chatham Strait (probably through Stephens Passage, inasmuch as that appears to be the main migration route of the pink salmon that pass Douglas Island).

TABLE 19.—*Pink salmon tagged near Douglas Island, Stephens Passage, July 31 to August 3, 1926—794 tagged, 181 returned (22.8 per cent)*

Locality of recapture	Number	Time, in days
Icy Straits, Spasskaia Bay	1	1
Chatham Strait:		
No details	1	5
Hawk Inlet	1	3
Point Marsden	1	4
Marble Bluffs	2	8-10
Basket Bay	2	4
Hood Bay	5	3-9
Tebenkof Bay	1	14
Frederick Sound:		
Keku Strait	1	60
Port Camden	1	(1)
Herring Bay	2	7
Pybus Bay	3	5-9
Frederick Sound—Continued.		
Cape Bendel	4	5-9
Cape Fanshaw	3	6-7
Stephens Passage:		
Douglas Island	34	1-44
Salmon Creek, Juneau	9	7-39
Taku Inlet	58	1-44
Glass Peninsula	2	8-10
Seymour Canal	5	3-9
Limestone Inlet	36	2-6
Snettisham Inlet	1	32
Windham Bay	4	6-9
British Columbia: Shelsey River (Taku system)	4	22-38

[1] Reported taken before date of tagging.

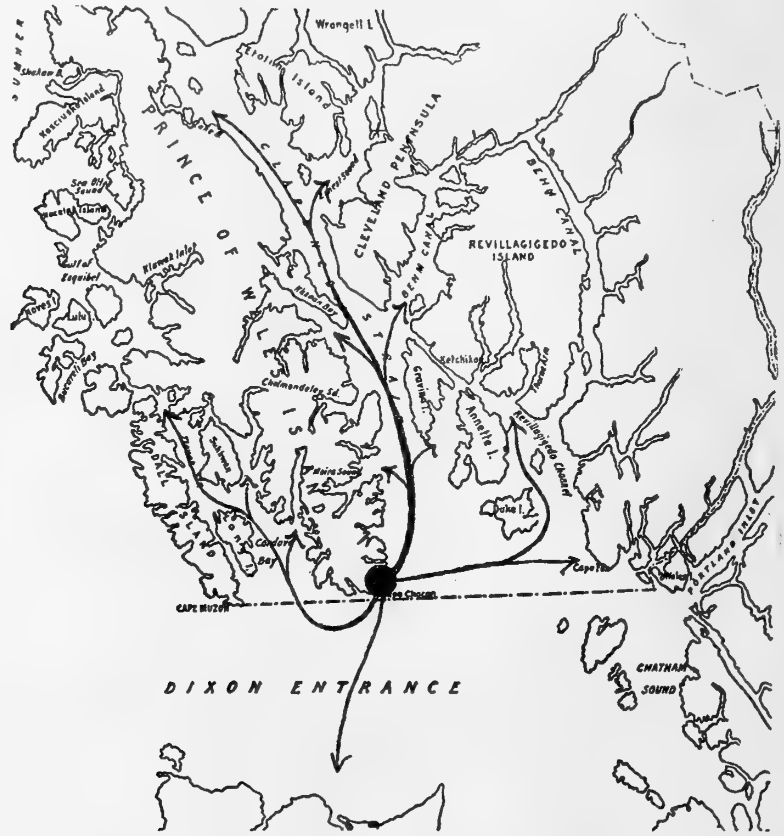

FIG. 16.—Distribution of pink salmon tagged at Stone Rock Bay, August 9, 1926

RETURNS FROM EXPERIMENTS AT STONE ROCK BAY, CLARENCE STRAIT

Five hundred salmon were tagged here on August 9. Four red salmon were tagged and one was recaptured in 5 days in Ingraham Bay, Clarence Strait, just a few miles north of the point where the tagging was done. Twelve cohos and 5 chums were tagged, but none of either species was returned; the remainder were pink salmon, and 132 were recaptured. The data are given in Table 20 and Figure 16.

TABLE 20.—*Returns from pink salmon tagged at Stone Rock Bay, August 9, 1926—479 tagged, 132 returned (27.6 per cent)*

Locality of recapture	Number	Time, in days	Locality of recapture	Number	Time, in days
West coast:			Clarence Strait—Continued.		
Hunter Bay	1	12	Point Caamaño	3	8
Kassa Inlet	2	12–13	Grindall Point	3	5–7
Coco Harbor	1	7	Windfall Harbor	2	4–6
Datzkoo Harbor, Dall Island	1	11	Kasaan	5	4–5
Grace Harbor	1	11	Stream at Kasaan	1	34
Kaigani Strait	5	3–11	Twelve Mile Arm	1	4
Cape Muzon	4	5–11	Daisy Island	1	9
Nunez Point	10	4–13	Skowl Point	1	3
Clarence Strait:			Tolstoi Bay	2	5
Cape Chacon	18	1–7	Whale Passage	1	7
Stone Rock Bay	2	3–8	Ernest Sound, Union Point	1	10
Island Point, Prince of Wales Island	4	1–3	Behm Canal, Betton Island	3	4
Ingraham Point	1	3	Revillagigedo Channel:		
Polk Island	3	6	Point Higgins	1	(1)
Moira Sound	9	4–9	Gravina Point	2	4–10
Halibut Creek	8	4–9	Hassler Harbor	1	37
Cholmondeley Sound	1	7	Point Alava	1	1
Skin Island	3	4	Hotspur Island	2	4
Dall Head	8	3–8	Foggy Bay	1	5
Driest Point	5	5–9	Tree Point	1	6
Nelson Cove	4	3–4	Dixon Entrance, Cape Fox Island	1	8
Bostwick Inlet	3	4–5	British Columbia, Massett Inlet, Graham		
Grant Cove	3	4	Island	1	8

1 Reported recaptured before date of tagging.

In 1925, 2,341 pink salmon were tagged at or near this same place between August 8 and 13. The results in the two years were virtually identical. The distribution was mainly along the west coast of Prince of Wales Island, in Clarence Strait, Behm Canal, Ernest Sound, and Revillagigedo Channel.

RETURNS FROM EXPERIMENTS IN KAIGANI STRAIT

Tagging was done here on August 10 and 11, and nearly 1,600 fish were handled.

RED SALMON

Out of 55 tagged 6 were returned, as follows: Two from Cape Ulitka, Noyes Island, 11 days after tagging; one each from Dall Head, 5 days; Moira Sound, 6 days; Kassa Inlet, 9 days; and Kaigani Strait, 2 days.

COHOS

Forty-six were tagged and 6 returned. One came from each of the following localities: Mountain Point, Revillagigedo Island, 18 days after tagging; Alder Grove, 18 days; Kassa Inlet, 20 days; Nichols Bay, 9 days; Unuk River, 45 days; and Annette Point, 37 days.

PINK SALMON

Of 1,479 tagged, 498 were recaptured. The returns came predominantly from the waters of the west coast of Prince of Wales Island, the southern part of Clarence Strait, and Revillagigedo. They are in entire agreement with the results of the tagging done at Cape Muzon and Kaigani Point in 1925. The data are given in Table 21 and Figure 17.

TABLE 21.—*Pink salmon tagged in Kaigani Strait, experiments 26 and 27, August 10 and 11, 1926—1,479 tagged, 498 returned (33.7 per cent)*

Localities of recapture	Number	Time, in days
West coast, Prince of Wales Island:		
Kaigani Strait	125	1–11
Howkan Narrows	9	4–5
Cape Muzon	58	2–11
Long Island	2	3
Nunez Point	6	7–12
Webster Point	13	3–12
Shipwreck Point	11	3–11
Cordiva Bay	1	3
Klakas Inlet	13	3–10
Kassa Inlet	5	9–12
Hunter Bay	5	1–11
Grace Harbor	8	8–13
Coco Harbor	6	6–7
Sukkwan Island	10	4–12
Hessa Inlet	2	6
Nutkwa Inlet [1]	39	2–11
Tlevak Strait	3	5–6
Datzkoo Harbor	14	5–11
Alder Grove	4	3–11
Lime Point	5	5–10
Hydaberg	4	4–8
Arboleda Point	3	6
Baker Island	8	2–11
San Juan Bautiste	1	5
Noyes Island	13	5–6
Cape Ulitka	1	7
San Christoval Channel	1	9
Klawak Inlet	1	8
Bocas de Finas	2	8–9
Hole in the Wall	1	10
Clarence Strait:		
Cape Chacon [2]	37	2–10
Stone Rock Bay	3	4–7
Island Point, Prince of Wales Island	1	8
Clarence Strait—Continued.		
Polk Island	3	4–8
Moira Sound	6	6–37
Halibut Creek	8	5–8
Skin Island	1	7
Dog Island	1	4
Hotspur Island	1	3
Dall Head	7	4–7
Driest Point	1	7
Nelson Cove	1	3
Grant Cove	2	5–6
North end Gravina Island	2	7
Grindall Point and Island [3]	4	4–9
Skowl Point and Arm	5	7–8
Windfall Harbor	2	7–8
Streets Island	8	5–13
Caamaño Point	1	7
Point Niblack	1	9
Ship Island	4	6–7
Meyers Island	2	6–7
Tolstoi Point	1	7
Frederick Sound, Francis Anchorage	2	12–14
Behm Canal, Betton Island	1	2
Revillagigedo Channel:		
Higgins Point	1	8
Bostwick Inlet	1	7
Traitors Cove [2]	1	(?)
Seal Cove or Bay	8	5–11
Gravina Point	1	9
Cedar Point (Smugglers Cove)	3	5–7
Crab Bay	2	7–8
Thorne Arm	1	42
British Columbia: Skeena River	1	9

[1] Two with date of capture not reported and one reported retaken before date of tagging.
[2] One reported taken before date of tagging.
[3] Two reported taken before date of tagging.

CHUMS

Eighteen were tagged and three recaptured. One was taken in each of the following localities: Cape Muzon, 8 days; Soda Bay, 9 days; and Nutkwa Inlet, reported taken before the date of tagging.

CONCLUSIONS

The percentages of tagged fish recaptured in each experiment are about the same as in the experiments of 1924 and 1925. The following table (Table 22) gives the percentages of recaptures for each experiment in which there was a sufficient number recaptured to make such percentages fairly reliable. The discussion of the percentage of returns given in the report on the tagging of 1924 and 1925 does not need to be modified in the light of the additional experiments of 1926 and need not be repeated here.

TABLE 22.—*Percentages of tagged fish recaptured*

Locality where tagged	Red	Coho	Pink	Chum	Locality where tagged	Red	Coho	Pink	Chum
Cape Fox	40.8	17.2	19.0	22.9	Icy Strait	26.8	-------	34.0	-------
Nelsons Cove	16.1	20.6	23.6	21.4	Douglas Island	41.6	-------	22.8	-------
Point Colpoys	19.0	-------	26.2	-------	Stone Rock Bay	-------	-------	27.6	-------
Cape Bendel	-------	-------	34.5	21.2	Kaigani Strait	-------	-------	33.7	-------
Parker Point	36.2	-------	34.6	-------					

The general routes of migration, as indicated by the experiments of 1926, were the same as outlined in the previous report. Fish entering Icy Strait are distributed mainly to waters tributary to Icy Strait, Chatham Strait, Lynn Canal (1925), and Stephens Passage. Those entering through the southern entrance to Chatham Strait go mainly to Chatham Strait, Frederick Sound, and Stephens Passage. Those entering Sumner Strait go mainly to Sumner Strait, Clarence Strait, Ernest Sound, Behm Canal, and Revillagigedo Channel; and those entering at Dixons Entrance are distributed to the west coast of Prince of Wales Island, the lower part of

FIG. 17.—Distribution of pink salmon tagged in Kaigani Strait, August 10 and 11, 1926

Clarence Strait, Behm Canal, Ernest Sound, and to the streams of northern British Columbia. In general, it appears that the fish enter the channels of southeastern Alaska through the entrance that provides the most direct route to the streams in which they will eventually spawn, and that they follow this most direct route without wide wandering.

Certain differences are shown in the distribution of red salmon tagged early in the season, as compared with salmon tagged later in the season at the same place. No such difference is clearly marked in the case of the other species. In the case

of red salmon tagged near Cape Fox, the early fish appear to be going primarily to Boca de Quadra and to the Nass River. Later in the season it appears likely that a larger percentage of the fish found in the region of Cape Fox have originated in the streams of British Columbia. In the region of Icy Strait the experiments have shown conclusively that the early run of reds contains an important element derived from the large rivers at the head of Lynn Canal. The later runs contain few if any Lynn Canal fish but do contain a large number of fish bound for Taku Inlet, which were not represented at all during the earlier part of the season.

As in the previous experiments, the distribution of the pink salmon and chums is shown to be predominantly to places located within a comparatively short distance from the point of tagging. This is probably due to the habit of these two species of spawning in all of the numerous small creeks of this region. The red salmon range more widely, but the cohos appear to be the most widely ranging of any of the species tagged.

ANNOTATED LIST OF FISHES COLLECTED IN THE VICINITY OF GREENWOOD, MISS., WITH DESCRIPTIONS OF THREE NEW SPECIES

By

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CONTENTS

INTRODUCTION

The collection of fishes upon which the present report is based was made mostly during the summer of 1925 by the junior author within a radius of about 8 miles of Greenwood, Miss., while engaged in an investigation relative to the use of fish for con-

trolling mosquito breeding.[1] It is believed that the species inhabiting the smaller, quiet waters of the vicinity (that is, the potential mosquito-breeding areas) are, with few exceptions, represented in the collection. However, time did not permit extensive collecting in the larger lakes. The Mississippi River was not visited and little collecting was accomplished in the near-by Yazoo, Yalobusha, and Tallahatchie Rivers. Pelucia and Big Sandy Creeks are the only fast-flowing streams visited, and, as explained elsewhere, collections from these streams were made only in their lower courses, lying within the flat delta region. Although a somewhat different fauna was met in the lower sections of these creeks, it seems highly probable that their upper stretches are populated by a number of typical creek species, which, of course, do not occur in the collection.

The most favorable collecting areas for a majority of the species were furnished by the many free-flowing artesian wells, near which ponds of fair size, swales, or sloughs usually are found. The waters frequently support an abundant plant growth, well known to be necessary as a direct source of food and even more so as an indirect source. Due to the heaviness of the soil, ponds are common along highways where excavations have been made in grading; and such waters, when containing a moderate growth of marginal vegetation and when of fair depth, usually support what might appear to be an incredible fish population, not only as to individuals but also as to the number of species. Most of these fish originally gained ingress to these isolated waters through the rather infrequent floods to which the locality is subject. The competition for food doubtless is severe in these ponds, but examinations of ingested materials show a difference in feeding habits among the species which would reduce such competition to a minimum.

These ponds or lakes support an abundance of minute crustaceans, copepods, in particular, furnishing an appreciable component of the diet of several species of fish. A decided preference for fry and minnows is evident among a considerable proportion of the local species, notably the crappies, and in such instances the top minnow Gambusia is extensively preyed upon, no doubt because of its abundance and comparatively unwary disposition. Upon final analysis, however, the basis of the diet of the great majority of the fish collected consists of the water boatman, Corixa, and to a less extent of the larvæ of the midge.

The water boatman is a rather inconspicuous little insect that gains its name from its manner of progress along the surface, the long swimming legs giving it the appearance of a boat propelled by oars. The adult is somewhat oval in form, 5 or 6 millimeters long, with mottled, brownish back and deep red eyes. The eggs are deposited under water, where they are attached to plant stems (Howard, 1912, pp. 273 and 274).

The next most important source of food is the minute, wormlike larvæ of the midge fly. The adult midge resembles the mosquito superficially, and, like the mosquito, deposits its eggs upon the surface of the water. The immature midges are about 6 to 7 millimeters in length, segmented, with wedge-shaped head, and translucent in color with conspicuous dark eye spots. The larvæ are present in the

[1] The authors wish to extend their thanks for laboratory facilities and numerous other conveniences to Dr. M. A. Barber, Dr. C. P. Coogle, and W. H. W. Komp, officers of the United States Public Health Service, all engaged at Greenwood, Miss., in researches concerning malaria during the period when the collections upon which the present list is based were made.

quiet waters in considerable abundance, and their dwelling habits apparently make them an easy prey of the fish.

Several distinct types of habitats are represented clearly by various ponds, and while a few species are present virtually always some show a marked adaptive preference, several species being found in single localities only.

The collecting was accomplished mostly with nets; four seines, varying in length from 12 to 300 feet, were found useful, while a dipnet was employed in small ponds and marshes. The greatest depth at which any collection was made did not exceed 6 or 8 feet.

DESCRIPTION OF THE COLLECTING PLACES

To obviate repetition in describing the environment of each species separately, the following brief descriptions of the various waters visited are appended. The place or places of collection are shown under each species in the list, and by referring to these descriptions the characteristics of the habitat may be ascertained.

BORROW PITS, ITTA BENA ROAD

Several roadside excavations about 6 miles southwest of Greenwood, near the Itta Bena Road, are of sufficient size to be classed as medium-sized ponds. The surrounding terrain is low, consisting of reclaimed swamp land, which drains into these pools, making them dependent largely upon the local rainfall. A fairly equable water temperature prevailed, however, due to moderate depth and the shade afforded by the surrounding forest.

The substratum is of the characteristic gray clay known as "gumbo." A feature that deserves particular notice, from the standpoint of its fish-cultural value, is the presence of the primrose willow *Jussiæa diffusa,* which covered not less than half the surface of the water at the time the collections were made and apparently was a noteworthy asset for game fish. In two of the ponds, which have a maximum depth of only 4 feet and an area of about one-eighth of an acre, other species also abounded. The smaller ponds of this group had been overfished with improvised nets, and their value as habitats could not be determined.

Some of these waters were much less overgrown with Jussiæa than others, and it was quite evident that those having the closer growth were comparatively clear, which, no doubt, is due to the obstructive effect the plants have upon the waves.

BORROW PIT AT MONEY

This large pond was distinctly muddy and perennials were entirely absent, the steep clay banks being 3 or 4 feet high, with an occasional shrub at the water's edge. It was excavated some years ago, but perennials were unable to establish themselves on account of the character of the margins. Pasture lands surrounded it, and shade was entirely lacking. The pond was 200 feet long, 30 feet wide, and 5 feet deep through the center at the time the collections were made.

BORROW PIT AT WAKELAND

This pond is near the railway, about 6 miles north of Greenwood and 1 mile south of Wakeland, and it is less than one-fourth the extent of the one described in the preceding section. The water is shaded during part of the day by a high railway embankment along one side and several small trees on the opposite shore. The water was moderately muddy, and perennials were almost entirely absent. Of special interest are the myriads of small shrimps (*Palæmonetes exilipes*) that were present and apparently found conditions favorable. Fish also were numerous, and 12 species were taken here, which was a larger number than occurred in other ponds of similar size.

BORROW PITS, GRENADA ROAD

This series of borrow pits had existed only about 2 years, and the vegetation was not plentiful in consequence. Several species of fish had become fairly well established, but as the maximum depth found in these ponds at the end of the dry season was only 2 feet, and as little shade is afforded, it is obvious that they would prove suitable for only a limited number of species.

SLOUGH AT BROWNING

An unusually large, free-flowing well at Browning, 4 miles east of Greenwood, forms a narrow slough over 100 yards in extent. The banks are high and wooded, and the water is 10 feet in depth in places, and, being clear and cool, it forms a favorable habitat in some essentials. The banks are too steep and shaded, however, to permit of any but a sparse growth of the usual aquatic plants, with the result that fish are present in rather limited numbers.

SLOUGH AT MONEY

This slough crosses the highway about 8 miles north of Greenwood and just north of Money. During seasons of high water it is connected with the near-by Tallahatchie River, but when visited it had become isolated. It occupies an old stream bed and was nearly 150 yards in length, with a maximum depth of approximately 4 feet at the time it was visited. The water was turbid and warm, and a cypress growth was present throughout half its length, leaving the remainder unshaded. While it would appear favorable to the growth of perennials, this type of vegetation (except for a narrow marginal stand of coarse grass, *Paspalum distichum*), was lacking and relatively few fish were present.

SLOUGH NEAR GREENWOOD

This slough is situated near the Memphis Road, 2 miles west of Greenwood, and as it is comparatively wide and shallow it might well be designated a pond. A near-by well flows into a slight hollow, forming this pond of less than 100 yards in length, 50 feet in width, and 18 inches deep through the center. There is a swale or marsh (equaling it in extent) at each end of this slough but they are of such a depth that Gambusia only are able to negotiate them. Large trees shade the water at intervals; but for the most part a profusion of marginal plants grows out to a depth of ½ foot,

forming an excellent habitat for several forms of animal life, particularly for the larval mosquitoes. The soil in this section exceeds the average in fertility and it supports a well-settled rural community. For this reason the pond is overfished. Large numbers of Gambusia are present, however, and it is probable that under less disturbed conditions a plentiful stock of the larger species also would be found there.

HADLEY OR ALLEN LAKE

Near the Grenada Road, at a distance of about 4 miles northeast of Greenwood, is situated one of the characteristic lakes of the Delta region. It has the appearance of a lagoon, being encircled by a tall cypress growth, which extends into the water to a depth of 4 or 5 feet, and as a dense shade is afforded, small marginal plants are virtually absent. This lake doubtless occupies an old river bed. It is about 1 mile long, 200 feet wide, and of moderate depth, with water, when visited, of medium turbidity.

Seines can not be used in waters of this type, as the cypress, upon completing its growth and falling into the water, apparently undergoes decay very slowly, causing the floor of the lake to be covered to such an extent that to use even small seines is out of the question. The result is that the fish have acquired an unusual degree of protection. Collecting was accomplished with copper sulphate, which was applied to a shallow pool, which had become separated because of a lower water level, at one end of the lake, and from the sample thus obtained it was quite evident that large fish abound in this lake.

ROEBUCK LAKE

Roebuck Lake occupies an old stream bed. It has a length of about 9 miles and an average width of 300 feet, giving it much the appearance of a river. Its maximum depth is about 12 feet, becoming quite shallow toward the ends, however. A scattered cypress growth is present along perhaps two-thirds of the shore line, the remainder being bordered by meadow lands. Fish of marketable size are present in quantities. One set with a 300-foot seine commonly yielded 200 pounds of edible fish. Other forms of life, particularly turtles, also abound.

Collections were made at two localities in Roebuck Lake, first along the shore at the foot of a meadow near the town of Itta Bena and next near one extremity of the lake, some 2½ miles southeast of Itta Bena. This latter section is surrounded by cypress trees, but the width is such that a considerable unobstructed area is available in the center, where seining is practicable, the water being only waist deep. Several collections in both of these places showed that the fish were much more plentiful in the deeper section, where the banks were largely clear of timbers. The buffalofish and the gar were the only species found in the timber-bordered section, while a considerable variety was present where more favorable conditions existed.

PELUCIA CREEK

The delta region terminates rather abruptly about 6 miles east of Greenwood, where a rapid incline marks the beginning of the uplands. Pelucia Creek, at a point near the Carrollton Road quite close to the foot of this incline, was visited. With an ordinary flow, this stream is 30 feet wide and about knee deep. It is subject to

floods, however, which raise the water to as high as 8 feet and widen the stream proportionately; and as its bed is of coarse sand, it has become eroded to such an extent that at ordinary times the water flows in a relatively thin sheet, in consequence of which it becomes very warm and, no doubt, very well aerated also.

The stream was muddy when visited. It is unshaded, except at rare intervals when it approaches the banks. The current in the straight stretches is too swift to be inhabited by many fish, but at fairly frequent intervals, where bends occur or where a tree lies in the stream, an eddy may be formed; and in such places fish usually were present, probably lying in wait for food brought down by the current. Perennials are almost entirely absent along the banks of this stream, and none were found growing directly in the water.

MISCELLANEOUS COLLECTING PLACES

In addition to the foregoing, a number of other places were visited but are not deemed of sufficient importance to be taken up separately, either for the reason that they do not represent types different from those already described or because collecting in them was not practicable with the means at hand.

1. **Polyodon spathula** (Walbaum)

SPOON-BILL CAT; PADDLE FISH

Squalus spathula Walbaum, Artedi Piscium, 1792, p. 522.

The unusual and even grotesque appearance of this strange fish is such that when once seen it is easily remembered, as it differs widely from all other fresh-water species. It resembles the sharks in several particulars and was classed with these forms by an early writer. This resemblance is due to the absence of scales, the unequally developed caudal, the high dorsal fin, and perhaps, also, to the form and position of the mouth, which superficially simulates that of the shark. Its most distinguishing feature, however, is the extended spatulate snout, which is approximately one-third of the length of the entire fish and is one-fourth as broad as it is long in specimens about 370 millimeters in length. It decreases in proportionate length with age.

The paddle fish occupies a separate category from the other fish composing this collection, as this primitive form does not develop the bony skeleton; but instead, the supporting structures are of cartilage.

Although of considerable commercial value locally during the winter, the paddle fish is not taken frequently during the remainder of the year, and only four apparently landlocked fish were obtained—three from a slough at Money and one from a lagoon near Lake McIntire. These approximated 680 millimeters (27 inches) in total length.

The condition of the gonads of these paddle fish (taken in early July) showed the sex elements to be far from mature. Virtually no information is available concerning its spawning habits. The smallest paddle fish recorded (as far as known to the authors) had attained a length of over 4 inches.

Examination of four stomachs indicates that only minute, free-swimming animal life, with little vegetation, had been ingested; and as sand and mud were entirely absent, it is probable that the paddle fish makes good use of its highly developed gills in straining this material from the water as it swims about; and it is presumable that the produced snout has its principal use as a sensory organ of value in determining the immediate presence of food, as it is traversed by two well-developed nerve tracts, one on each side of the heavy central cartilage, and its entire surface is sprinkled with sensory pits. The form of this organ is such that it would be well adapted to stirring over the detritus. The small eyes, unless of unusual power, are of slight use in locating the minute creatures fed upon, as most of them are almost transparent and in the muddy waters sometimes frequented by the paddle fish would be virtually invisible. Although it is an awkward fish and might appear poorly equipped to compete with other forms, it is essentially a specialist, in that it makes use of the animal plankton, which is largely neglected by the other mature species

of this section, with the exception of the large-mouthed buffalo fish, the jack shad, and the round sunfish, which approach the paddle fish in their feeding habits. It seems certain that little difficulty is experienced in obtaining this plankton material, as all of the stomachs examined were well filled, although one of these fish was taken in a lagoon near Lake McIntire, which supported an unusually dense fish population.

In the limited number of stomachs examined copepods constituted the basis of the diet; and although the larvæ and pupæ of the midge, *Coretha*, had been taken in quantities, they are present during only a comparatively short period, of course.

2. **Lepisosteus osseus** (Linnæus)

LONG-NOSED GAR; BILL-FISH; SHELL GAR; SPIKE-BILL GAR

Esox osseus Linnæus, Syst. Nat., Ed. X, 1758, p. 313.

Only large individuals of this species were taken. Two skins, from fish 890 and 1,180 millimeters (35½ and 47¼ inches) long, were preserved and no stomach examinations were made.

The long-nosed gar was not met often, although it may frequent the deeper waters of the rivers and thus have escaped notice. It seems probable, however, that it is primarily a still-water fish and that it is not abundant locally. As its common name implies, this form is characterized by a prolonged beak; and as it is said to frequent submerged brush piles, this specialized organ may be used as "forceps" in obtaining its prey.

With the exception of the produced snout, this gar is very much like the other two species in shape and color. The dorsal surface of the head is plain olivaceous with two fine median dark lines, beginning just posterior to the nostrils and terminating just anterior to the eyes. When measured at a distance of one-third of its length from the tip, the width of the beak is contained from 16 to 18 times in the distance from its tip to the eye. There are from 16 to 24 fulcra in a single row on the anterior edge of the first dorsal ray. The 62 scales in the longitudinal series conform too closely to the number present in the other gars to serve as a distinguishing character.

This species was taken only in Roebuck Lake, where specimens 4 feet in length are quite common and which, according to published accounts, is about the maximum size attained.

3. **Lepisosteus platostomus** Rafinesque

SHORT-NOSED GAR; DUCK-BILL GAR; "ALLIGATOR GAR"

Lepisosteus platostomus Rafinesque, Icththyologia Ohiensis, 1820, p. 72.

Fifteen specimens of this gar, ranging in length from 320 to 630 millimeters (13 to 25 inches), were preserved, measured, and examined as to spawning condition and stomach contents. This is the smallest of the gars, as it is reported to reach a length of only 2 to 3 feet.

Of the three species collected, the "short-nosed" gar was by far the most numerous, and it apparently frequents both rivers and lakes. The rather swift, muddy rivers, however, offer the most favorable environment, for here this species was found to exceed greatly all other fish in the numbers present. Being a comparatively sluggish fish, it is netted easily; but this would not account for the relative frequency with which it was taken in the rapid river currents.

In the vicinity of Greenwood (and probably over a wider section) the short-nosed species is known as the "alligator gar." *L. tristœchus*, however, is much more generally designated as the alligator gar in literature, and this name is more appropriate for the last-mentioned species because of the very large size attained.

With reference to the length and width of snout, the short-nosed gar is intermediate between the long-nosed species (*L. osseus*) and the alligator gar (*L. tristœchus*). The width of the beak, measured just posterior to the fleshy tip, is contained from 6 to 7 times in the total length of the snout.

The heads of the other species of gars are almost plain olivaceous, whereas the short-nosed gar sometimes bears about 9 transverse, dark gray bands, which may be quite distinct on the olivaceous ground color. One specimen has six of these bands between the tip of the snout and the eyes and three between the eyes and the nape. Dorsally, this gar is gray to olivaceus, becoming lighter ventrally, the lower surface being white. The dorsal, caudal, and ventral fins usually are

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pale straw color and frequently bear several distinct dusky spots. With reference to the number of fulcra on the dorsal fin, this species again is intermediate, bearing from 8 to 14 of these modified scales in a single row along the anterior edge of the first ray of the dorsal. The rows of scales on the sides in all three species are too close to serve as distinguishing characters.

Except for the head, the gars bear a fairly close resemblance to each other. The long, cylindrical body is incased in an armor of heavy, platelike scales, which, no doubt, afford effectual protection from almost all of their natural enemies. The gars are utilized as food by some of the negroes. The roe of this fish, however, is said to be poisonous.

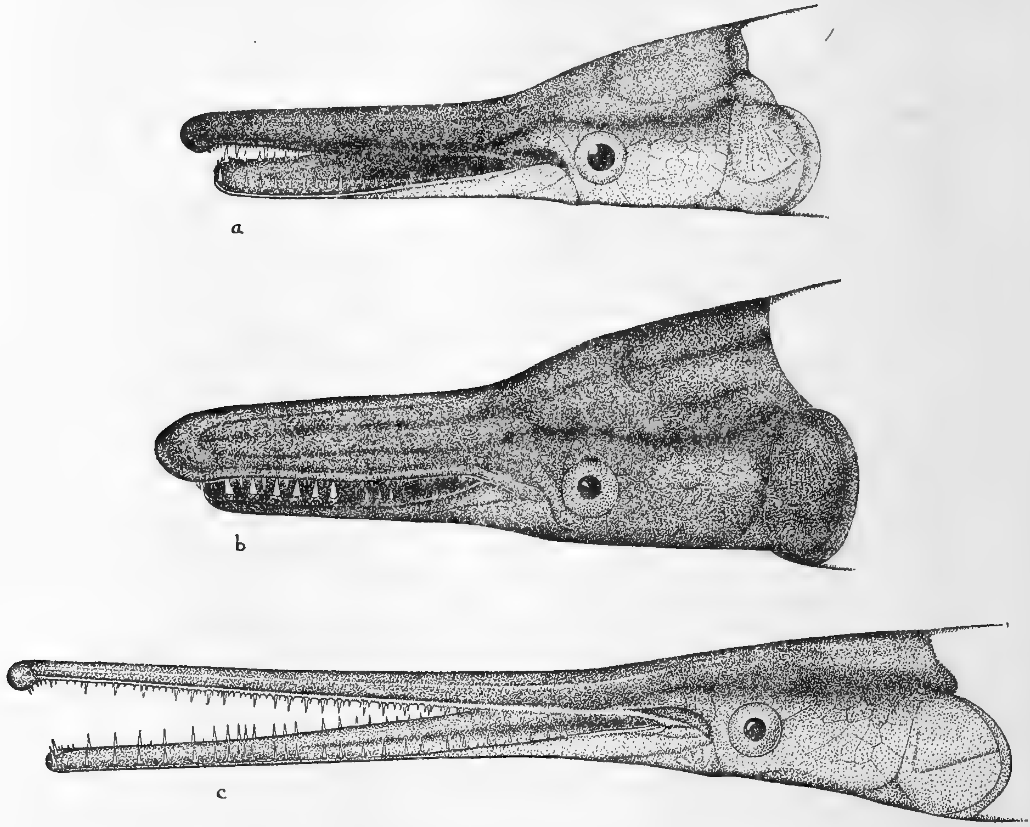

Fig. 1.—Heads of the gars. *a, Lepisosteus platostomus; b, L. tristoechus; c, L. osseus.* From specimens taken at Greenwood, Miss., in 1925

The short-nosed gar appears to have an extended spawning period, as mature eggs were found in fish taken from late June to late September. The ovary of a 630-millimeter (25 inches) fish contained approximately 6,300 ripe eggs, which averaged 2 millimeters in diameter.

Beetle fragments composed the bulk of the contents of 15 stomachs examined. The small shrimp (*Palæmonetes exilipes*) was utilized somewhat and small fish only rarely. The ingested material apparently undergoes rather thorough mastication before reaching the short, thin-walled digestive tract.

Its distribution is general throughout this section, frequenting rivers, lakes, and ponds; but the rivers apparently afford the most favorable conditions.

4. **Lepisosteus tristœchus** (Bloch and Schneider)

ALLIGATOR GAR; GREAT GAR

Esox tristœchus Bloch and Schneider, Syst. Ichthy., 1801, p. 395.

A single small specimen, 675 millimeters (27 inches) in length, was taken, and it seems probable that this gar is uncommon in the vicinity of Greenwood. The specimen was shown to a local fisherman of experience, who stated that he had not previously seen a gar like it. The short-nosed gar (*L. platystomus*) is known locally as the alligator gar.

This gar is distinguished readily from the short-nosed form by its shorter and wider beak. The width of the organ (measured just posterior to the fleshy tip) is contained 4.2 times in the distance from the tip of the beak to the eye. The body, also, is deeper and broader than in the other species, and it has the appearance of being a more formidable fish. According to published accounts, this species reaches a length of 20 feet. The heavy jaws, with teeth reduced in numbers but considerably enlarged and more or less pear-shaped, probably are especially adapted to rapaceous feeding habits, enabling the fish to utilize larger forms than do the other species. The digestive tract in all of the gars is very short and thin-walled, and the indications are that the food undergoes relatively thorough mastication before it reaches the stomach. The remains of a fair-sized fish, with an appreciable amount of vegetable material, were present in the only stomach examined. The single alligator gar in the collection was taken on September 21, 1925, near the southeast end of Roebuck Lake.

5. **Amia calva** Linnæus

"GRINNEL"; GRINDLE; DOGFISH; BOWFIN

Amia calva Linnæus, Syst. Nat., ed. 12, 1766, p. 500.

The grindle has the unusual distinction of being the only surviving species of an entire order and family of fishes now chiefly represented by numerous fossils. Its tenure of life after removal from water is remarkable, and in this respect it was found to exceed even the gar. Fourteen specimens, ranging from 170 to 770 millimeters (6⅗ to 30⅓ inches) in length, were preserved and examined for foods consumed.

The grindle is essentially a compact fish, with powerful jaws, the throat being protected by a gular plate, an osseus lamina between the lower jaws. The grindle frequents virtually all of the lakes and ponds of the region, and it seems to prefer relatively warm waters. It is esteemed by the negroes locally as a table fish and is considerably sought for this purpose.

This fish spawns in the spring and not only guards the eggs during incubation but also protects the young during the early stages. Examinations of the gonads of 16 fish taken during the summer and fall showed them to be in an early stage of development.

An examination of the intestinal contents of several specimens indicated the grindle to be a light feeder; and, being rather sluggish, it seems probable that it consumes less than a game fish of equal size. Although its general appearance suggests a voracious appetite, fish of fair size, or up to 450 millimeters (17¾ inches), were found to have utilized mostly insects ordinarily found near the surface, among which the water boatmen (*Corixa*), dragon-fly nymphs, and the whirligig beetle were the most frequent. The small shrimp (*Palæmonetes exilipes*) also appears to be taken frequently, and an appreciable amount of vegetation usually was present with the other material. The grindle attains a considerably greater length, however, than 450 millimeters, and the larger fish probably require a more substantial diet. One specimen of 770 millimeters (30⅓ inches) had swallowed a fish about 8 inches in length. The 14 grindles collected were taken in a borrow pit and slough at Money, in Hadley or Allen Lake, and in a lagoon near Lake McIntire.

6. **Dorosoma cepedianum** (Le Sueur)

JACK SHAD; SKIP JACK; "SCISSOR-BELLY SHAD"; GIZZARD SHAD

Megalops cepedina Le Sueur, Journ., Ac. Nat. Sci., Phila., I, 1818, p. 361.

Although of slight value, directly, as a food fish, the jack shad, through utilizing the fine plankton largely neglected by most other fish, furnishes the carnivorous species a valuable source of food. The specialized gill rakers (which, on the first arch, numbered close to 350 in a specimen 95 millimeters in standard length) enable it to utilize this microscopic material, which undergoes the first stage of digestion in the thick-walled gizzardlike stomach. The intestine slightly exceeds the fish in length. Copepods predominated in the seven stomachs examined, with an appreciable quantity of Daphnia and fine vegetation also present.

Gravid females were taken in June. One of these, 315 millimeters in length, contained approximately 50,000 eggs, being more prolific, probably, than any other fish of the region.

The jack shad is represented in the collection by 12 specimens, ranging in length from 58 to 315 millimeters (2⅖ to 12⅖ inches), collected in a borrow pit along the Itta Bena Road and in a borrow pit at Wakeland.

Genus ICTIOBUS Rafinesque

The following key is introduced to show the distinguishing characters noticed by the authors, who experienced some difficulty in identifying the species.

KEY TO THE SPECIES

a. Mouth large, oblique; upper lip on or above level of lower margin of eye; lips thin and nearly smooth; gill rakers long and numerous, 38 to 55 on first arch .... *cyprinella*, p. 114

aa. Mouth smaller, less oblique to inferior; upper lip much below level of the lower margin of eye; lips thickened, more or less striate; gill rakers shorter and only about half as numerous as in the preceding.

b. Back notably elevated and strongly compressed; depth of body (in Greenwood specimens) 2.4 to 2.5 in length; vertical distance from origin of dorsal to a straight line running through the center of eye to lateral line on base of caudal equal to or greater than head; ventral outline from chin to ventrals nearly straight; anterior rays of dorsal strongly elevated, the longest one equal to length of head; mouth small, inferior, more strongly protractile downward than forward .... *bubalus*, p. 115

bb. Back less strongly elevated and less strongly compressed; depth of body (in Greenwood specimens) 2.75 to 3.15 in length; vertical distance from origin of dorsal to a straight line running through center of eye to lateral line on base of caudal, notably shorter than head; ventral outline more strongly curved; anterior rays of dorsal shorter, the longest one 1.25 to 1.55 in head; mouth a little larger, oblique, protractile forward rather than downward .... *urus*, p. 115

7. **Ictiobus cyprinella** (Cuvier and Valenciennes)

BIG-MOUTH BUFFALO; RED-MOUTH BUFFALO; "GOURD-HEAD BUFFALO"

Sclerognathus cyprinella Cuvier and Valenciennes, Hist. Nat. Poiss., XVII, 1844, p. 477.

This common buffalo fish is represented in the collection by 16 specimens ranging in length from 200 to 485 millimeters (8 to 19⅛ inches). Much variation in depth among specimens exists. For example, in two fish, each 250 millimeters in standard length, the depth varies from 82 to 97 millimeters. This fish differs from the other species in the large oblique mouth, thin lips, and weak pharyngeal teeth, characters usually given in keys; also in the much more numerous and more slender gill rakers, the first arch supporting 38 to 55 rakers, exclusive of the fleshy ridges on the lower part of the arch, whereas in the other species this arch has only about half that many. Forbes and Richardson (1908, p. 70), however, state that *I. cyprinella* has 75 gill rakers on the first arch. This appears to show either a wide variation (if the identifications be correct) among individuals or a difference in the number of gill rakers with age. The five specimens from Greenwood examined with

respect to this character ranged from 225 to 400 millimeters in length, and the smallest of these had 55 and the largest 51 gill rakers, whereas a specimen 305 millimeters long had only 38. These counts do not suggest a variation with age but a rather large difference among individuals.

With reference to the size attained locally, the gourd-head buffalo is intermediate of the other two species of buffalo fish recorded in this report and was less frequently taken than either of them. It is quite common, however, and is a valuable food fish.

An examination of 25 stomachs of all three species shows an appreciable difference in the feeding habits, and their divergence in form may be correlated with this factor.

The gourd-head buffalo, according to six stomachs examined, depends upon the minute plankton crustaceans and, to a less extent, the free-swimming insect larvæ for the basis of its diet, in this respect closely resembling the spoonbill catfish. These two fish were the only ones that had utilized the almost transparent midge larvæ Corethra. Vegetation was used sparingly. Forbes and Richardson (1908, p. 70) found about a third of the stomach contents in 17 specimens examined to consist of vegetable matter and the other two-thirds consisted of aquatic insects and Entomostraca.

The large mouth and well-developed gill rakers (which are fully twice as numerous as in the two related species herein considered) seem well adapted to obtaining this type of food. A muscular expansion of the stomach forms a sort of gizzard, and the intestine is relatively long, being almost three times the length of the fish. These structures would suggest a vegetable diet greater than has been shown by the stomachs examined.

The reproductive organs in six specimens taken during the summer and fall were all in a collapsed condition. The spawning period is reported to occur during the early spring (Forbes and Richardson, 1908, p. 70).

A deep slough at Browning was well stocked with this species, and it was collected in a borrow pit and in a slough at Money, in Hadley or Allen Lake, Roebuck Lake, and in a lagoon near Lake McIntire.

8. **Ictiobus bubalus** (Rafinesque)

SMALL-MOUTH BUFFALO; RAZOR-BACK BUFFALO; QUILL-BACK BUFFALO

Amblodon bubalus Rafinesque, Journal Physique, 1818, p. 421.

This species is represented in the collection by 22 specimens, ranging in length from 160 to 370 millimeters (6¼ to 14½ inches). It is characterized chiefly by the high, compressed back and long, falcate dorsal fin, the last-mentioned character giving origin to the name "Quill-back." Other characters are shown in the key.

This is the smallest and probably the least important, economically, of the three buffalo fish collected in the vicinity of Greenwood. Although this species is reported in some sections of its range to reach a weight somewhat less than 40 pounds, the largest one taken locally during the summer weighed only 3 pounds, and the average was much smaller.

Disintegrating, darkened plant fragments were estimated to constitute fully 80 per cent of the diet, with the remainder usually consisting of copepods and midge larvæ in 8 stomachs examined. The inferior mouth and straightened ventral line characterize it as a bottom feeder. It has a less effective straining apparatus than *I. cyprinella*, as its gill rakers are not quite as long and only about half as numerous. The intestine approximates two and one-half times the length of the body, placing this fish intermediate in this respect of the other two buffalo fish collected locally.

The spawning season in the south is said to occur during March and April. The specimens examined, all of which were taken during the summer, had passed the spawning period. This species was collected in a slough at Browning, Roebuck Lake, Mossy Lake, and in a slough near Sidon.

9. **Ictiobus urus** (Agassiz)

MONGREL BUFFALO; "ROOTER"; "LINER"

Carpiodes urus Agassiz, Amer. Journ. Sci. Arts, XVII, 1854, p. 355.

This species is represented by 15 specimens, ranging from 225 to 420 millimeters (9 to 16½ inches) in length. It is characterized principally by the low, rounded back, convex ventral outline the moderate mouth (which is protractile, forward and downward), and the less strongly falcate dorsal fin as compared with the other species. These differences are recognized by local fishermen.

From an economic point of view, the liner is probably in advance of the other two buffalo fish locally, as its average size is greater and it is more abundant.

While its diet, as shown by nine specimens examined, resembles somewhat that of the gourd-head, in that it had eaten a moderate amount of the plankton crustaceans, it also had made use of comparatively coarse insects, particularly the abundant water boatman (*Corixa*) and midge larvæ. Possibly in consequence of this coarse diet, the stomach is more muscular, is better developed than in *I. cyprinella*, and is about twice the size of that of *I. bubalus*. In comparison with the other two, its intestine is the shortest, being slightly over twice the length of the body, and the intestinal walls are notably thicker.

Nine specimens taken during the summer were examined for the condition of the gonads; the spawning season evidently was past. In Illinois this species is reported to spawn in the spring (Forbes and Richardson, 1908, p. 72).

The liner was collected in borrow pits on the Itta Bena Road in Hadley or Allen Lake, in a lagoon near Lake McIntire, and in a brickyard pond in Greenwood.

10. **Carpiodes difformis** Cope

River carp

Carpiodes difformis Cope, Proc., Am. Phil. Soc., Phila., 1870, p. 480.

We refer 32 specimens, ranging from 35 to 160 millimeters (1⅖ to 6⅖ inches) in length, somewhat doutbfully to this species. The body appears to be unusually slender, the depth (in nine specimens 75 to 160 millimeters long) varying from 2.9 to 3.15 in length, and the back is little

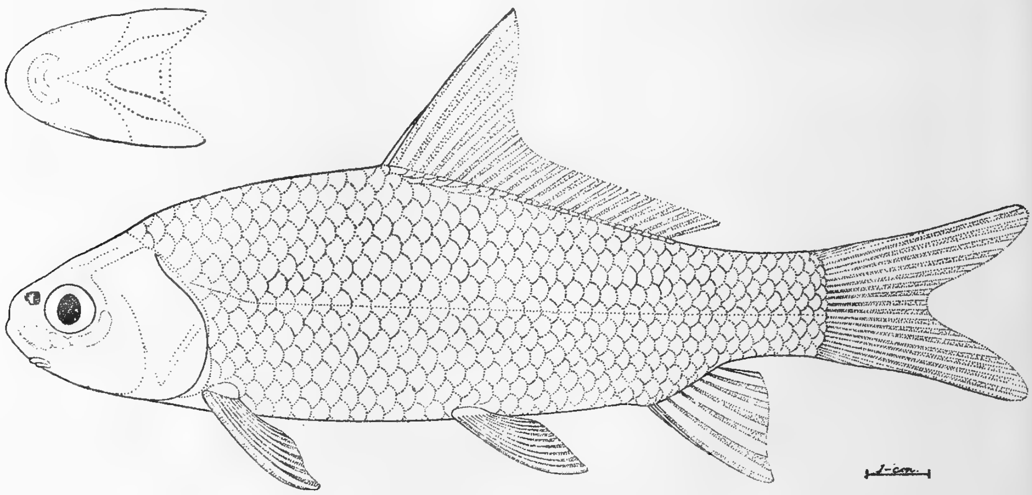

Fig. 2.—*Carpiodes difformis*, from a specimen from Greenwood, Miss., taken in Pelucia Creek, June 23, 1925

elevated. The interorbital space is contained 2.55 to 2.8 in head; snout 3.45 to 3.9; tip of lower lip under posterior nostril; scales in lateral line, 36 or 37; dorsal fin notably elevated in front, the longest ray in the large specimens reaching middle of base of dorsal and fully equal to length of head; the number of rays vary from 25 to 27.

The branchial arches, with their numerous long gill rakers (about 45), almost encircle a bulbous enlargement at the cranial base, constituting an extremely effectual straining apparatus. The relative value of this unique strainer, or selective apparatus, may be gauged by comparing this species with *Hybognathus nuchalis*, in which the bulbous enlargement is wanting. Although both species ingest the same type of material, the river carp appears to be able to obtain a greater proportion of organic material with the ingested mud. From an examination of the intestinal contents of four specimens it would appear that over 90 per cent of the ingested material consists of sand

and mud, only a minor quantity of organic material being present. The entire intestine, which is slightly over three times the length of the fish, remains virtually the same size throughout, and as it is usually well filled it is probable that food is taken continuously. The inferior mouth of this river carp also indicates it to be a bottom feeder, and as it was found only in the eddies of Pelucia Creek (a rapid stream, where organic matter is rather scarce) it seems probable that large quantities have to be taken in order to provide sufficient nutritive material.

The species was collected on June 19 and 23 and September 16, and only in Pelucia Creek. The condition of the sexual organs of the fish would indicate that spawning takes place early in the spring.

11. **Hybognathus nuchalis** Agassiz

Silvery minnow

Hybognathus nuchalis Agassiz, Amer. Journ. Sci. Arts, XIX, 1855, p. 224.

The collection contains 55 specimens, ranging from 25 to 110 millimeters (2⅘ to 4⅖ inches) in length. This fish, like the river carp, ingests quantities of sand and mud with a comparatively small proportion of fine organic material. This minnow, however, possesses an inferior straining apparatus, but, on the other hand, its intestine is proportionately about twice the length of that of the river carp or six times the length of the fish; and as the tracts (in specimens examined) always were filled throughout, the silvery minnow appears to be capable of little selection of the material it ingests in feeding on the bottom, and comparatively large quantities are taken.

Spawning occurs in this region principally in June and July. A fish 80 millimeters long contained 480 apparently mature eggs approximating ½ millimeter in diameter. This is primarily a stream-dwelling form, and 46 of a total of 55 specimens were taken in Pelucia Creek; the others were from borrow pits at Money, Browning, and near the Grenada Road.

12. **Notemigonus crysoleucas** (Mitchill)

Golden shiner; Roach

Cyprinus crysoleucas Mitchill, Rept., Fishes, New York, 1814, p. 23.

This shiner is represented in the collection by 87 specimens, ranging in length from 57 to 150 millimeters (2¼ to 6 inches). No larger representatives of the species were seen. The specimens are quite uniform in color and structure. Even the depth between young and adults (the young usually being more slender) does not vary greatly, as in 13 specimens, ranging in length from 58 to 145 millimeters, the variation of the depth in length of body is only 3.4 to 3.95. The scale formula in the same specimens is 10 or 11–48 to 56–4 or 5; dorsal 9 to 11; anal 13 to 16.

This species, which locally appears to inhabit only the quiet waters, has a markedly varied diet. Many individuals had fed entirely upon vegetation, consisting of darkened, disintegrating plant fragments, filamentous algæ, or seeds, while others had taken appreciable quantities of minute crustaceans, principally Cladocera. The digestive tract usually is well filled, and it is probable that the shiner has little difficulty in obtaining its food. This tract slightly exceeds the length of the fish. Its walls are thin and the stomachic dilation is hardly perceptible.

The spawning period is considerably extended. Forbes and Richardson (1908, p. 128) give May as the principal spawning time. Some of the Greenwood specimens, taken in July and August, contain well-developed roe. The ovary of a fish 100 millimeters in length, taken August 17, contained approximately 1,500 nearly matured eggs.

The shiner is a favorite bait for bass in the South. It was taken only in the following small bodies of waters: Borrow pits, Itta Bena Road; borrow pit at Money; borrow pits, Grenada Road; slough at Browning; and slough near Greenwood.

13. **Notropis atherinoides** Rafinesque

Shiner

Notropis atherinoides Rafinesque, Amer. Month. Mag., 1818, p. 204.

We refer to this species with much doubt, one specimen, 36 millimeters (1½ inches) long, taken in a slough near Money. The specimen does not agree with current descriptions of *atherinoides*, in that the dorsal fin has 11 rays instead of 8, and it is inserted only slightly behind the base of the

ventrals. Its origin is about equidistant from tip of snout and base of caudal. The specimen has only a faint lateral band.

14. Notropis cooglei n. sp.

SPOT-TAILED MINNOW

The authors are aware of the complexity of the group of fishes assigned to the genus Notropis and of the inadequate definitions of many of the species. Under the circumstances, they naturally hesitate to add another name. It has been impossible, however, after examining available literature and making comparisons in the National Museum with supposedly related forms, to identify the specimens at hand with any known species. As no other course appears to be open, we propose for them a new name and describe the specimens as follows:

Diagnosis.—Body deep, compressed, depth 3.55 to 4.05 in standard length; snout pointed, as long as eye; mouth terminal, oblique; pharyngeal teeth 4–4 or 1, 4–4, 1, hooked; dorsal rays 9

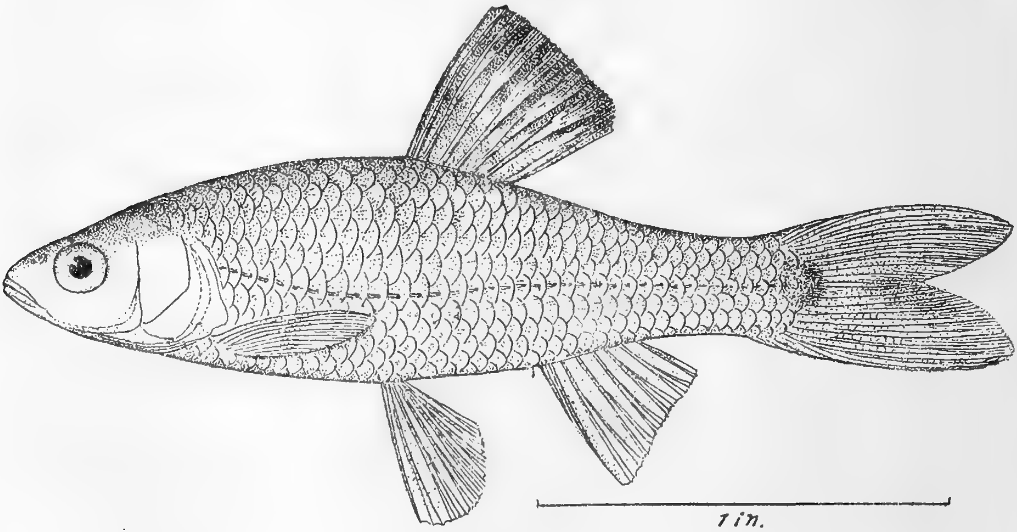

FIG. 3.—Notropis cooglei n. sp. From a paratype

or 10; origin of fin a little behind ventrals; anal rays 10 or 11; scale formula 6 or 7–37 to 42–4 or 5, from 15 to 18 in advance of dorsal; exposed part of scales on sides notably deeper than long; lateral line strongly decurved; an evident dark caudal spot present.

Description of type.—Body deep, compressed; the back elevated, the depth 3.65 in length; head 4.15; snout short, 3.33 in head; eye 3.75; mouth rather large, oblique; maxillary not quite reaching front of eye, 3.75 in head; interorbital convex, 2.5; scales notably deeper than long on sides, 38 in lateral line, 7 between lateral line and origin of dorsal, 4 between lateral line and origin of anal; lateral line complete, decurved, far below axis of body; origin of dorsal a little behind insertion of ventrals or midway between tip of snout and base of caudal, margin of fin nearly straight, the anterior rays not reaching the tips of the posterior ones when deflexed; caudal fin deeply forked, both lobes pointed and of equal length; origin of anal at vertical from end of dorsal base and a little nearer base of caudal than margin of opercle, outer margin of fin slightly concave; ventral fins reaching slightly beyond origin of anal; pectorals pointed, 1.15 in head.

Color.—Bluish silvery above, becoming pale silvery underneath; sides posteriorly with a diffuse plumbeous band; an evident black caudal spot present; dorsal fin pale, with numerous, dusky punctulations, giving the fin a generally smoky appearance, particularly distally; caudal fin pale, with somewhat fewer dusky punctulations than the dorsal; the other fins yellowish in life almost white in spirits.

Variability.—The specimens at hand show a rather high degree of uniformity of the various proportional measurements taken, as well as in fin and scale counts. In 17 specimens, varying in

standard length from 36 to 65 millimeters, the following range in measurements and counts resulted: Head, 3.9 to 4.25 in standard length; depth, 3.55 to 4.05; eye, 2.9 to 4 in head; snout, 3.1 to 4; interorbital, 2.4 to 3.35; maxillary, 3.2 to 4; depth of caudal peduncle, 2 to 2.55; pectoral fin, 1.1 to 1.45; scales, 6 or 7–37 to 42–4 or 5, from 15 to 18 in advance of dorsal; dorsal rays, 9 or 10; anal rays, 10 or 11. Pharyngeal teeth, 4–4, or about equally 1, 4–4, 1 (nine specimens examined for this character). In color, some of the specimens are much darker than others. This may be due, in large part, to the preservative used, as some of the specimens were preserved in alcohol and others in formaldehyde. In general, the latter are lighter in color, but the caudal spot appears darker and more distinct. This spot is not always equally distinct, and in a few rather poorly preserved specimens it is wanting.

Holotype.—No. 88379, United States National Museum, standard length 61, total length 76 millimeters, Pelucia Creek, Greenwood, Miss., June 19, 1925.

Paratypes—Thirty-six specimens, 20 to 52 millimeters, obtained with the type; 24 specimens, 20 to 60 millimeters, June 23, 1925; 70 specimens, 20 to 53 millimeters, July 6, 1925; 55 specimens, 29 to 55 millimeters, September 16, 1925, all from Pelucia Creek; 29 specimens, 19 to 65 millimeters, July 6, 1925, Big Sandy Creek, Valley Hill, Miss.

The species is named for Dr. C. P. Coogle, of the United States Public Health Service, to whom the authors are indebted for valuable aid in making the collection upon which the present report is based.

This spot-tailed minnow, according to the contents of 15 stomachs, is primarily insectivorous. A few specimens were found that had taken quantities of sand and mud, but as the intestine is relatively short, scarcely equaling the length of the body, this fish seems unsuited to this type of material. Vegetable material, in the form of algæ, and plant fragments, too, had been taken in moderate quantities. The basis of the diet in the specimens examined, however, consisted of the frequent water-boatman, Corixa.

Spawning may take place over an extended period. Gravid fish were collected during July and August. A male, with numerous tubercles on its head, was taken as late as September 16. A full-grown female, 64 millimeters in length, contained approximately 600 mature eggs, and another minnow of 44 millimeters contained less than one-half that number.

15. **Semotilus atromaculatus** (Mitchill)

CREEK CHUB; HORNED DACE

Cyprinus atromaculatus Mitchill, Amer. Month. Mag., II, 1818, p. 324.

This minnow appears to be of infrequent occurrence in this region, as it was taken only once when two small specimens were collected in a slough near Browning. These fish were each 41 millimeters (1⅝ inches) long.

The intestinal tracts in the small specimens collected equaled three-fourths of the total length of the fish. One of the fish had ingested hundreds of minute insect eggs and the other had taken several small insects.

The scarcity of this species may be due to the absence of suitable waters in this locality, for the creek chub is reported to show a distinct preference for creeks, increasing in abundance toward the headwaters of small streams. Due to the flatness of the land, the creeks in the immediate vicinity of Greenwood are rather sluggish, and therefore are not typical of the waters usually frequented.

16. **Ictalurus furcatus** (Le Sueur)

BLUE CAT; FULTON CAT; MISSISSIPPI RIVER CAT

Pimelodus furcatus, Le Sueur, in Cuvier and Valenciennes, Hist. Nat. Poiss., XV, 1840, p. 136.

A single young individual, 195 millimeters long, was taken. This species may be distinguished at once from the related species by the long anal fin, which has 36 rays (in our specimen), and its base is contained 1.05 in the predorsal length. It is evident, also, when comparing other Ictalurus of about the same size, that the body is heavier and deeper, the dorsal profile in advance of dorsal is steeper; the eye is smaller, being contained 5.45 times in the head, or 8 times in the predorsal length; the barbels are all shorter and weaker than in other Ictalurus of the same size, the maxillary barbel scarcely reaching the gill opening; and the predorsal distance is much shorter than the distance between the dorsal fins.

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The specimen at hand had fed on fish, insects, crustaceans (Daphnia recognized), and apparently on plants. The single very young individual in the collection was taken in the Tallahatchie River on June 26.

17. Ictalurus punctatus (Rafinesque)

CHANNEL CAT; FIDDLER

Silurus punctatus Rafinesque, American Monthly Magazine, 1818, p. 359.

This common species is represented by 11 specimens, ranging in length from 82 to 350 millimeters (3¼ to 14 inches). It differs from related forms in the narrow head and snout, the prominent bony ridges on the head, and in the slender caudal peduncle. This fish usually has black spots on the sides, which form a ready recognition mark. These marks are wanting in all the specimens from Greenwood, however, except one, and that one is very sparsely flecked.

The channel cat, although known to enter standing and sluggish water occasionally, appears to be fairly well confined in its habitat to streams. One individual at hand was taken in a sluggish slough; all the others were caught in faster running water.

According to Jordan and Evermann (1902, p. 22), the channel cat spawns in April and May in Louisiana. The gonads in the two larger individuals in the present collection, taken July 14 and September 16, were in early stages of development. All the others were too small to have reached sexual maturity.

Four specimens were examined for food. The diet consisted of fish and insect and plant fragments. The specimens were collected in Pelucia Creek, near Browning, and in a slough near Lake McIntire.

18. Ictalurus anguilla Evermann and Kendall

"FORKED-TAIL CAT"; "WILLOW CAT"; "MUD CAT"; EEL CAT

Ictalurus anguilla Evermann and Kendall, Bull., U. S. Fish Com., XVII, 1897 (1898), p. 125, pl. 6, fig. 1.

This species is represented in the collection by 19 specimens, ranging in length from 95 to 400 millimeters (3¾ to 16 inches), all taken in quiet waters.

The specimens from Greenwood differ in one character from the type with which we have compared them, which is constant among our specimens—namely, in the notably more anterior position of the dorsal fin. In the Greenwood specimens the origin of the dorsal is much closer to the tip of the snout than the origin of the adipose, and the distance from tip of snout to the origin of the dorsal is equal to the space between the dorsal fins. In the type the origin of the dorsal is equidistant from the tip of the snout and origin of the adipose, and the distance from the tip of the snout to the origin of the dorsal is shorter than the distance between the dorsal fins. No other differences of importance were noticed. The following proportions and counts are based on nine specimens, ranging in length from 120 to 400 millimeters. Head 3.7 to 4.1 in length to base of caudal; predorsal distance 2.75; greatest width of head 1.75 to 1.9 in predorsal distance; length of snout 2.3 to 2.65 in head; width of snout at base of maxillary barbels 2.2 to 2.45; eye 4 to 7.35; interorbital space 1.75 to 2.3; depth of caudal peduncle 2.55 to 2.7; dorsal spine 1.4 to 1.85; pectoral spine 1.45 to 2.05. Dorsal rays I, 6; anal rays (including rudiments) 26 or 27. The color of the specimens is uniformly dark. A few of them have a crowding of dark punctulations on the side, making dark specks, in that respect resembling the usual color pattern of *punctatus*.

This species is recognized by the low, broad head, very broad snout, low ridges on the head and the deep caudal peduncle (2.55 to 2.7 in head, or 3.8 to 3.9 in predorsal distance, in *anguilla;* 2.8 to 3 in head, 4 to 4.45 in predorsal distance, in *punctatus*).

The gonads of 10 fish taken during the summer and fall were all in an early developmental stage, and it is probable that spawning takes place in the spring, as in related species.

The ingested material found in 10 specimens indicate that this fish is a voracious, carnivorous feeder. The diet varied considerably but was composed largely of insects and fish. The water boatman, Corixa, appeared frequently, with immature midges, dragon flies, and minute crustaceans in appreciable quantities. The willow cat also ingests considerable vegetation. An unusual diversity is apparent in the feeding habits of this fish, which is most evident in specimens caught in lakes and ponds, where a variety of foods exists from which to choose. One willow cat, 365

millimeters long, taken in Roebuck Lake, had ingested quantities of a water weed and insects in about equal amounts; the insects present were midge larvæ and dragon-fly nymphs. A second specimen, 152 millimeters long, from the same lake, had swallowed 20 crappies, each approximately 1 inch long; and a third willow cat, of 345 millimeters, also from Roebuck Lake, had taken thousands of water boatmen, Corixa. The largest specimen collected, having a length of 600 millimeters, had swallowed a member of its own species approximately 6 inches in length.

The willow cat was collected at the following localities: Borrow pit, Itta Bena Road; borrow pit at Wakeland; and Roebuck Lake. The borrow pits on the Itta Bena Road yielded more of this species than the other localities. The species appears to be an inhabitant of standing or sluggish water only, in which it is common at Greenwood.

19. **Ameiurus nebulosus** (Le Sueur)

COMMON BULLHEAD; BROWN BULLHEAD; SPECKLED BULLHEAD; "POLLY-WOG CAT" (YOUNG)

Pimelodus nebulosus Le Sueur, Memoir., Mus. Hist. Nat., V, 1819, p. 149.

A few dozen specimens, ranging from 85 to 350 millimeters (3½ to 14 inches) in length, were preserved. The fish vary considerably in shade; that is, some are dark bluish to blackish, whereas others are light olivaceous, but the mottled form (*marmoratus*) was not taken. The range in anal rays (including rudiments) in 18 specimens is as follows: One with 20, one with 22, two with 21, eight with 23, five with 24, and one with 25.

This catfish was taken somewhat less frequently than the willow cat. Locally, it shows a preference for ponds well supplied with vegetation, and in no instance was it found in running water.

This common catfish, as shown by published accounts, has a varied diet. It is generally described as being carnivorous. Forbes and Richardson (1908, p. 188), however, found specimens that had fed on "distillery slops and accidental rubbish." Ten specimens examined in the Greenwood collection contained mainly darkened, disintegrating plant fragments, which apparently had been collected on the floor of the quiet waters in which the specimens were taken. Only one, the largest, 13¾ inches long, had taken an appreciable amount of animal matter, and this specimen contained portions of a good-sized fish.

While this fish is known to reproduce in the spring, it is probable that the spawning period may be considerably extended, as a fish 235 millimeters long, taken August 27, was approaching maturity, the ovary containing approximately 3,000 eggs, which averaged 1.25 millimeters in diameter.

With the exception of the borrow pit near the Itta Bena Road, where a large brood of young fish was noticed, the bullhead was found only in small numbers at the following localities: Slough near Greenwood, borrow pit at Money, borrow pits on Grenanda Road, Hadley or Allen Lake, and a brickyard pond at Greenwood.

20. **Ameiurus natalis** (Le Sueur)

YELLOW CAT; YELLOW BULLHEAD

Pimelodus natalis Le Sueur, Memoir., Mus. Hist. Nat., V, 1819, p. 154.

A single small specimen, 55 millimeters long, was secured in Hadley Lake. This species is recognized principally by the long anal fin, which has 27 rays in the specimen at hand. Comparing this fish with specimens of *nebulosus* of the same size, the head appears to be somewhat broader and the tail fin is distinctly rounded in *natalis*, whereas it is emarginate in *nebulosus*. The other common species, *melas*, to which these species are related, was not obtained.

21. **Leptops olivaris** (Rafinesque)

"YELLOW CAT"; MUD CAT; GOUJON

Silurus olivaris Rafinesque, American Monthly Magazine, 1818, p. 355.

Only three small individuals, respectively 66, 75, and 305 millimeters (2⅗, 3, and 12⅕ inches) in length, were taken. This species reaches a very large size, individuals weighing 75 and even 100 pounds having been reported. It is recognized by the extremely low, broad head; very small eye, placed high on the head; projecting lower jaw; and the short anal fin, which is composed of only 12 to 15 (15 in each specimen at hand) rays.

In the vicinity of Greenwood the yellow cat appears to be a stream fish and was found only in the rapid waters of Big Sandy Creek near the Valley Hill station. It may inhabit the near-by rivers, but, as stated elsewhere, the extent of collecting accomplished in these waters was negligible. Big Sandy Creek closely resembles Pelucia Creek and, although the latter was seined upon numerous occasions, the yellow catfish was taken nowhere except in Big Sandy Creek.

Stomach examinations of the three specimens in the collection showed it to be a decidedly carnivorous form. The largest specimen had swallowed one of its own species, approximately 25 millimeters long. The other two had fed upon small fish and insect larvæ.

In Illinois (Forbes and Richardson, 1908, p. 194), the yellow cat spawns during April and early May. The local spawning period could not be determined from the small specimens available.

22. **Schilbeodes gyrinus** (Mitchill)

TADPOLE CAT

Silurus gyrinus Mitchill, American Monthly Magazine, 1818, p. 322.

Two specimens, 52 and 57 millimeters (2 to 2⅕ inches) in length, were taken in company with the willow cat in a borrow pit situated on the Itta Bena Road, which was largely overgrown with the primrose willow. The species was not seen elsewhere. In this species the adipose fin is continuous with the caudal, without a definite notch, the pectoral spines have no bony hooks, and the jaws are equal.

23. **Fundulus notatus** (Rafinesque)

TOP MINNOW; TOP-WATER MINNOW; BLACK-BANDED MINNOW

Semotilus notatus Rafinesque, Ichthyologia Ohiensis, 1820, p. 86.

This minnow, widely distributed through the central plains region and the Gulf drainage, is represented in the present collection by 10 specimens, ranging in length from 36 to 80 millimeters (1½ to 3⅛ inches). In the adult the males are distinguished from the females by the much more numerous black specks above the dark lateral band. The female generally has only one or two rows of dark specks above the lateral band, whereas the male has several rows and is speckled everywhere except on the back in advance of dorsal. In the female the lateral band is uniformly black and definitely defined, both above and below. In the male the lateral band is crossed by short black bars, at least anteriorly, which are a little greater in length than the width of the band and extend slightly below it and sometimes also slightly above it, making the outline of the lateral band irregular.

This is the most conspicuous minnow of our inland waters, apparently always present at the surface, where it may be seen from a distance, and in swimming it leaves ripples on the water, resembling in these respects the cuatro-ojo, or four-eye (*Anableps dowii*), of Central America. In the South Atlantic drainage this species is replaced by the related *F. nottii*, which appears to be identical in its habits.

In its feeding habits this minnow, according to eight stomachs examined, appears to be omnivorous, taking appreciable quantities of vegetation but relying principally upon terrestrial insects of comparatively large size, which probably are taken as they fall into the water. The stomachic dilation is slight and the intestine approaches one-half the total length of the fish.

The ovary of a minnow 70 millimeters long, taken June 30, 1925, contained 40 ripe eggs approximately 1.25 millimeters in diameter and an equal number of eggs only one-half as large, indicating that spawning may take place two or more times during one season. Repeated spawning does not appear to be unusual in this group of fishes.

The 10 specimens at hand were collected at the following localities: Slough at Browning, Hadley or Allen Lake, Pelucia Creek, a pond at Valley Hill railway station, and Big Sandy Creek.

24. **Fundulus kompi** n. sp.

The collection contains 31 specimens of Fundulus, ranging in length from 36 to 63 millimeters (1½ to 2½ inches), which we are unable to identify with any known species, and therefore we propose for them a new name and describe them as follows:

Diagnosis.—Body moderately deep, compressed, depth 3.8 to 4.45 in standard length; head broad, depressed; interorbital broad, 2.15 to 2.5 in head; origin of dorsal a little behind origin of anal, the fin with 8 or 9 rays; anal with 10 or 11 rays; scales 32 to 36 in lateral series, 16 to 18 oblique rows between upper angle of gill opening and origin of dorsal; females in alcohol plain grayish; males with 6 or 7 dark crossbars.

Description of type, male.—Body moderately deep, compressed; outline straight over head, convex from nape to dorsal; head depressed, flat above, head 3.8 in standard length; depth 4; snout broad, its length 3.75 in head; eye 3; interorbital 2.15; caudal peduncle 1.55; mouth nearly terminal, the lower lip only slightly in advance of the upper; teeth in the jaws in bands, the outer series enlarged; scales firm, 33 in a lateral series, 18 oblique series between upper angle of gill opening and origin of dorsal, enlarged scales extending forward on snout; dorsal fin with 8 rays, its origin over anterior third of anal, equidistant from middle of eye and tip of caudal; caudal fin round; anal fin somewhat larger than the dorsal, with 10 rays, its origin a little nearer end of caudal than tip of snout; ventral fins rather small, scarcely reaching vent, inserted equidistant from tip of snout and base of caudal; pectoral fins reaching base of ventrals, 1.5 in head.

Color.—Grayish-brown above, becoming pale underneath; a prominent dark median stripe on back in advance of dorsal; sides with six dark crossbars and with a faint dark spot above base of pectoral, suggesting a seventh bar; no dark blotch below eye; dorsal fin slightly dusky, with blackish

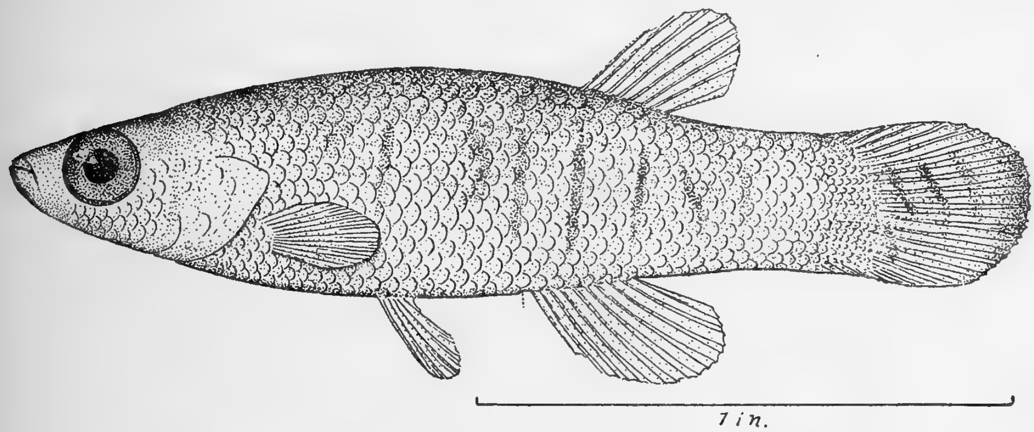

FIG. 4.—Fundulus kompi n. sp. From a paratype (male)

spots on posterior interradial membranes; caudal fin pale, with small dark spots on basal two-thirds; anal fin pale, with some dusky punctulations and indications of a few dark spots on posterior interradial membranes; ventrals and pectorals colorless.

Variability.—The smaller specimens (females) appear to be more elongate and less strongly compressed than the adults and they look rather strikingly, in general appearance and color, like female Gambusia. The dorsal and anal fins are lower in females than in males. The color in life of a male (paratype) 40 millimeters in length was olivaceous above, pale blue-green on sides, and cream underneath. The crossbars were green. The fins were colorless, except for reddish spots on the posterior interradial membranes of the dorsal and anal and on nearly the entire caudal. In alcohol the females are plain color, being brownish gray above and pale underneath. A distinct median dark line extends from the nape to the dorsal fin. The fins are all plain unspotted.

Holotype.—No. 88380, United States National Museum, standard length 39, total length 50 millimeters, borrow pit along the Greenwood–Itta Bena Road, June 12, 1925.

Paratypes.—Seven specimens, from type locality, taken on May 22 and October 2, 1925, and 23 specimens from the same pond, collected during August, 1927.

The relationship of these specimens appears to be with the coastwise swamp species, *F. chrysotus*, from which they differ (as determined by a comparison of specimens from Greenwood and from Florida (*F. chrysotus*)) in the more anterior position of the dorsal fin, as compared with the distance from the eye. The fins generally are longer, and the color of both males and females is different.

The species is named for W. H. W. Komp, of the United States Public Health Service, who was engaged at Greenwood, Miss., in research pertaining to malaria when the present collections were made. Mr. Komp rendered much valuable aid in the conduct of the work and the authors take pleasure in naming this fish for him.

This small fish was taken only in a borrow pit near the Itta Bena Road, where it was very plentiful, frequenting a growth of primrose willow, *Jussiæa diffusa*, along the shallow margins, with Gambusia, whose dwelling and feeding habits it appears to simulate. It is a more active fish than Gambusia, however, and better suited to survive where game fish are present in numbers, which was the condition in this pond. A determination of its food was not made from stomach examinations; when confined in an aquarium, mosquito larvæ were taken readily shortly after the fish was captured. The tract is short and thick-walled, approximating three-fourths of the length of the fish. A gavid female, 63 millimeters long, was taken in June, its ovary containing 150 eggs.

25. Gambusia patruelis (Baird and Girard)

TOP MINNOW

Heterandria patruelis Baird and Girard, Proc., Acad. Nat. Sci., Phila., VI, 1854, p. 390.

We follow Hubbs (1926a, p. 38) in using the specific name *patruelis*, replacing the name *affinis*, long used for this species. Mr. Hubbs produced evidence indicating that *affinis* apparently belongs to another species, which seems to be of limited distribution, being known, to date, only from the San Antonio–Guadalupe River system of Texas; whereas the present species ranges from southern Indiana and Illinois southward to the Gulf coast. Due to its wide distribution, abundance, and top-feeding habits, this minnow is a factor of importance in the control of mosquito breeding and is widely employed in the South for this purpose. It is extremely prolific and swarms in virtually all permanent waters where conditions favor mosquito production.

Its diet is varied, and besides insects and other animals of suitable size it has been found to utilize vegetation and even the young of its own species. There is only a slight stomachic dilation, and the relative length of the intestinal tract apparently varies with the sex. In six adult male specimens, 28 to 31 millimeters long, it averaged 42 per cent of the total length of the fish; whereas in six females, 35 to 39 millimeters long, it averaged 57 per cent of the total length.

The eggs of Gambusia develop within the female, and the young are brought forth at a relatively well-developed, active stage and having an average length of 8 millimeters. The breeding season commences in the early spring and continues through August and, to a limited extent, into September. The size of the brood in general varies with that of the female parent. For example, a 29-millimeter fish produced 5 young, whereas a 50-millimeter fish produced 77 young. Broods ranging upward of 200 fish have been reported for the related species *G. holbrooki*.

It has been shown by Barney and Anson (1921, p. 58) and Hildebrand (1927, p. 392) that a great seasonal difference takes place in the sex ratio of adult Gambusia; that is, the males are proportionately much fewer in midsummer than during the rest of the year. The difference, according to rather extensive statistics recently produced by Hildebrand, vary from 1 male to 2.54 females in June to 1 male to 11.3 females in August. Hildebrand also produced extensive evidence in corroboration of Geiser's (1924, p. 198) contention that a 1 to 1 sex ratio exists in young Gambusia. The question then arises, what becomes of the males afterwards? A definite answer can not be given, but Geiser (1924, p. 201) and Hildebrand (1927, p. 400) have produced evidence showing that the males are less resistant than females to adverse condition, and it seems probable that the males constitute the weaker sex. It appears to be of interest to mention, in this connection, that among a lot of 184 adult Gambusia taken from a slough at Browning on August 6, which were heavily infested with a parasite forming conspicuous external cysts, the ratio was 1 male to 25 females. Possibly the scarcity of males was due to their low resistance to the parasite. Although the males were few in this slough, the minnows were numerous, notwithstanding the fact that it was a favorite place for collecting Gambusia for bait.

Gambusia were present in all local waters, with one exception, this being a borrow pit at Money, where the crappie is abundant and protection in the form of marginal vegetation is almost absent. The most favorable habitat was in a section of a brook that passes through a hog yard situated near the city. Several hundred Gambusia were collected. The largest males were 33 millimeters ($1\frac{1}{3}$ inches) long, and the largest females were 50 millimeters (2 inches) in length. The male is not distinguishable externally from the female until it attains a length of about 20 millimeters, at which size the anal fin usually has assumed its characteristic form—that is, the anterior rays have become

elongated and bear bony hooks at the tips. It then forms an organ used in conveying the sperms from the male to the female.

The species of this genus are highly useful for the reduction of mosquito breeding. A large degree of natural control is provided by these fish throughout the South, east of the Rocky Mountains, where their distribution is quite general. In a number of the Southern States efforts have been made to distribute Gambusia to waters it had not reached through natural channels. Gambusia has been introduced in several States and many foreign countries to aid in abating the mosquito nuisance. In some localities it has not survived because the winters were too cold; in others it met enemies it could not combat. Several importations, as in Italy, Spain, and the Hawaiian Islands, have proved very beneficial. For an account of a rather exhaustive study of the effectiveness of Gambusia as an eradicator of mosquito larvæ, the reader is referred to Public Health Bulletin No. 153, United States Public Health Service (1925, Washington). *Gambusia holbrooki* was used in the studies reported upon in this bulletin. Somewhat similar studies were carried on later with *Gambusia patruelis*, which gave similar results. It may be stated that in general the degree of mosquito control provided depends partly upon the number of fish present but to a greater extent upon the amount of protection against fish which the mosquito larvæ receive from the presence of plants and flotage.

26. **Aphredoderus sayanus** (Gilliams)

PIRATE PERCH

Scolopsis sayanus Gilliams, Jour., Acad. Nat. Sci., Phila., IV, 1824, p. 81.

This fish probably is not abundant locally, as only nine specimens, ranging in length from 48 to 87 millimeters (2 to 3⅖ inches), were taken. The pirate perch is of much interest to the naturalist who has not yet been successful in explaining satisfactorily the unusual phenomenon of the change in position of the vent that takes place with age. For the vent is "normally" placed in the young; that is, it is posterior to the ventral fins. It gradually moves forward, however, as the fish grows, and finally occupies a place on the isthmus between the gill covers. Forbes and Richardson (1908, p. 231), in discussing this subject, state that a comparison of food of specimens of various ages gave no hint for the reason of this extraordinary step in development.

The rather unusual development of the pelvic girdle, which arches into the center of the abdominal cavity, thereby reducing the space somewhat, may have some correlation with the anterior position of the vent in the adult. In adult perch the pelvic arch is traversed by the small intestine, which enters the arch posteriorly and proceeds anteriorly to the jugular vent. The small intestine is comparatively short, averaging only about 25 per cent of the total length of the fish, and by traversing the girdle in its anterior progress along the floor of the abdominal cavity it occupies a space that could not be used more economically by another organ. An examination of nine stomachs showed that immature insects, principally midge larvæ, had been taken by the pirate perch, with virtually no other food in evidence. Forbes and Richardson (1908, p. 230), in examining 19 stomachs, also found most of the food to consist of insects and insect larvæ, and only two of the specimens had eaten fish.

Two females taken at Greenwood on September 30, 1925, were approaching the spawning period; the larger of these, measuring 87 millimeters in total length, contained approximately 1,100 eggs. Forbes and Richardson (1908, p. 231) found spawning fish at Meredosia, Ill., in May. This appears to suggest a long spawning period. The nine specimens at hand were taken from borrow pits on the Itta Bena Road and the Grenada Road.

27. **Boleosoma camurum** Forbes

Boleosoma camurum Forbes, Bull., Ill. Lab. Nat. Hist., II, 1878, p. 40.

This small darter is represented by 14 specimens, ranging in length from 32 to 43 millimeters (1¼ to 1¾ inches). The species is characterized by the incomplete lateral line, which extends only under the spinous dorsal, and by the distantly placed dorsal fins, the tips of the spines of the first dorsal scarcely reaching the origin of the second dorsal when deflexed. The cheeks, opercles, and chest are all fully scaled in the specimens at hand.

Insects only, consisting chiefly of midge larvæ were found in the eight stomachs examined. This fish was taken in a borrow pit at Craigside, where it was common, and one specimen was secured in a sluggish stream at Browning.

28. Copelandellus fusiformis (Girard)

Boleosoma fusiformis Girard, Proc., Bost. Soc. Nat. Hist., 1854, p. 41.

This species does not appear to be very common locally, as only four specimens, ranging in length from 28 to 40 millimeters (1⅛ to 1½ inches), were taken. In this species the lateral line is incomplete, ending under the base of the second dorsal or somewhat in advance of that point, and it is notably curved upward, following the outline of the back. The premaxillaries are not protractile. The head in the specimens in hand is contained 3.7 to 4 in the standard length; depth 5.15 to 5.35; D. IX–9 to 11; A. I, 6 to 7; scales 50 to 55.

Only fragments of insects were found in the three stomachs examined. The specimens were taken in a borrow pit near Craigside and in a very sluggish stream at Browning.

Genus POMOXIS Rafinesque; Crappies

KEY TO THE SPECIES

a. Eye of moderate size, 3.1 to 5.4 in head, equal to or shorter than snout; gill rakers of moderate length, shorter than snout.

b. Body usually not very deep, the depth 2.4 to 2.7 in standard length; dorsal profile deeply concave over eyes, more or less S-shaped in outline; mouth moderately oblique, a straight line from posterior margin of maxillary and perpendicular with anterior margin of premaxillary usually passing in front of base of dorsal; dorsal spines usually 6, rarely 5, occasionally 7 (among 55 specimens, 1 had 5 spines, 44 had 6, and 10 had 7 spines); sides often with indications of dark crossbars; anal often dusky, but without black spots ---- *annularis*, p. 126

bb. Body usually deeper, the depth 2.25 to 2.6 in standard length; dorsal profile less deeply concave over eyes, the outline less strongly S-shaped; mouth rather strongly oblique, a straight line from posterior margin of maxillary and perpendicular with anterior margin of premaxillary, usually passing well behind origin of dorsal; dorsal spines usually 7, rarely 6, occasionally 8 (among 43 specimens, 4 had 6 spines, 30 had 7, and 9 had 8 spines); sides usually more profusely spotted with dark, the markings not tending to form crossbars; anal fin usually with dark spots---- *sparoides*, p. 127

aa. Eye very large, 2.6 to 2.9 in head, distinctly longer than snout; gill rakers long and slender, equal to length of snout; body not very deep, the depth 2.55 to 2.85; dorsal profile scarcely concave over eyes; mouth quite oblique, a straight line from posterior margin of maxillary and perpendicular with anterior margin of premaxillary, passing somewhat posterior to origin of dorsal; dorsal spines 7, occasionally 8 or 9; color plain, the vertical fins usually more or less dusky, without definite dark spots---- *barberi* n. sp., p. 128

29. Pomoxis annularis Rafinesque

WHITE CRAPPIE

Pomoxis annularis Rafinesque, Amer. Month. Mag., 1818, p. 41.

The diagnostic characters of this and the related species are shown in the key presented herewith. In separating this species from *sparoides*, any one of the characters mentioned can not always be relied upon, as all of them either overlap or are at times indistinct. A comparison of three or more characters, therefore, often is necessary for positive identification.

Of the two common species of crappie (white and black), this one appears to be the most numerous locally, occurring in a ratio of about two to three. Forbes and Richardson (1908, p. 240) indicate it as having a more southern range than the black crappie, *P. sparoides.* At Greenwood the two species frequently were taken together in the same ponds.

In their feeding habits the two common crappies are very similar, as in this region both appear to subsist largely upon small fish; and in this respect they are a distinct aid to the mosquito, in that their principal food, according to the contents of 51 stomachs examined, consists of the top minnow, Gambusia, which in the South is the most effective natural enemy of the mosquito. The fish diet was supplemented largely by the water boatman, Corixa, and to a less extent by the shrimp, *Palæmonetes exilipes*. The young white crappie utilized copepods almost exclusively until an approximate total length of 90 millimeters was attained, when a rather definite transfer to the adult diet was noted. The young black crappie, on the other hand, also utilized the minute crustaceans, but was frequently found to have taken fish when it had attained a length of only 70 millimeters. In addition to the copepods, the young crappie had utilized to a much less extent, also, Cladocera and phyllopods.

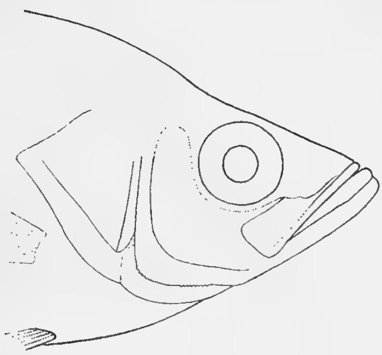

FIG. 5.—Outline of head of *Pomoxis annularis*. From a specimen 145 millimeters long

The spawning season at Havana is in May, as indicated by Forbes and Richardson (1908, p. 239). A crappie 135 millimeters long, taken June 16, 1925, contained approximately 1,200 ripe eggs, which, no doubt, is below the average production, as this fish was a comparatively small one.

Ninety-four specimens, ranging in length from 55 to 360 millimeters (2⅕ to 14⅕ inches), were preserved. These were collected at three localities: Borrow pit on the Itta Bena Road, slough at Money, and borrow pit at Craigside.

30. Pomoxis sparoides (Lacépède)

BLACK CRAPPIE; CALICO BASS

Labrus sparoides Lacépède, Hist. Nat. Poiss., III, 1802, p. 517.

In general, as shown in the key, this species has a deeper body than *annularis*, less deeply concave dorsal profile, more oblique mouth, and in color it generally differs in being more definitely spotted, none of the dark markings being arranged so as to form crossbars, as is often the case in *annularis*, and the spots usually are extended on the anal fin. In *annularis* the interradial membranes of the anal fin frequently are dusky, but this color is not broken up into spots as in *sparoides*.

In this region the black crappie simulates the white crappie in its fish and insect diet, as shown by a comparison of the food contents of 42 stomachs of the former and 51 stomachs of the latter. It thrives, however, when small fish are not available and under these circumstances was found to utilize the plankton crustaceans, including copepods, Cladocera, and ostracods, in lieu of the small fish. The insect component of the diet, which consisted largely of the water boatman, Corixa, appeared never to be lacking. The young black crappie apparently subsists almost entirely upon copepods and under normal conditions changes to the adult diet when it approximates 80 millimeters in length. In all three species listed the stomach is large and the length of the intestine is contained about three and one-half times in the total length of the fish.

On account of their frequency and predatory habits, these fish locally are by far the most formidable enemy of the mosquito-destroying minnow, Gambusia, which in this region forms the basis for the fish diet of the crappies. In addition to Gambusia, small bass, sunfish, and the young of their own kind were found to have been ingested.

In an attempt to determine whether the young crappie was of value as a mosquito-larvæ eradicator, 100 fish, approximating 1 inch in length, were confined to an area of 120 square feet in a borrow pit, and this inclosure was compared with another in which no fish were present. In this instance the results were entirely negative, as the young crappie apparently ignored the numerous larval mosquitoes during the whole course of the experiment, which was conducted over a period of two months.

This fish is suited to a variety of habitats, thriving equally as well in muddy water as it does in clear water, being found in large numbers in a borrow pit at Money, where vegetation was almost absent and the water was excessively muddy.

Spawning takes place in May at Havana, Ill. (Forbes and Richardson, 1908, p. 241), and it is probable that the season is about the same at Greenwood.

The 60 specimens preserved range in length from 58 to 290 millimeters (2⅓ to 11⅖ inches) and are from the following localities: Borrow pit, Itta Bena Road; borrow pit at Money; slough at Browning; Hadley or Allen Lake; and Roebuck Lake.

31. **Pomoxis barberi** n. sp.

Big-eyed crappie

The collection contains nine specimens of this crappie, ranging in length from 136 to 152 millimeters (5⅓ to 6 inches), which we describe as a new species.

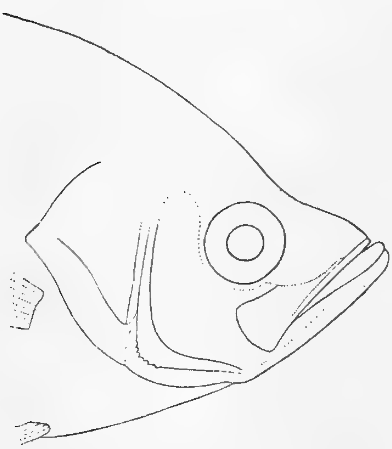

Fig. 6.—Outline of head of *Pomoxis sparoides*. From a specimen 140 millimeters long

Diagnosis.—Body moderately slender for a Pomoxis, its depth 2.55 to 2.85 in standard length (2.25 to 2.6 in *sparoides* and 2.4 to 2.7 in *annularis*); dorsal profile scarcely concave over eyes, even less so than in *sparoides;* eye very large, its diameter much greater than distance from tip of lower jaw to eye (this distance about equal to diameter of eye in *annularis* and *sparoides*), 2.6 to 2.9 in head (comparing specimens of equal size, the eye is contained in head 3.15 to 3.55 in *annularis* and 3.1 to 3.4 in *sparoides*); mouth rather strongly oblique, a straight line from posterior margin of maxillary and perpendicular to the anterior margin of premaxillary, passing somewhat posterior to origin of dorsal; gill rakers long and slender, about equal to length of snout, 15.5 in standard length, as compared with about 18 in related species; dorsal spines usually 7, occasionally 8 or 9; color rather plain, no indications of crossbars, anal fin sometimes more or less dusky, not spotted.

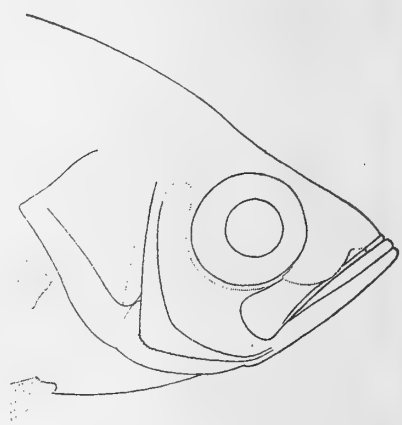

Fig. 7.—Outline of head of *Pomoxis barberi*. From a paratype 143 millimeters long

Description of type.—Body moderately slender, compressed, outline over eyes scarcely concave; head 2.85 in standard length; depth 2.7; snout short, pointed, 4.75 in head; eye very large, 2.7; interorbital 5.45; caudal peduncle rather long and slender, its depth 2.55 in head; mouth quite oblique; lower jaw projecting, extending into the dorsal profile; maxillary reaching opposite middle of eye, 2.15 in head; a line from posterior margin of maxillary and perpendicular to the anterior margin of the premaxillary passing through base of third dorsal spine; teeth in jaws pointed, in bands; gill rakers long, slender, 21 on lower limb of first arch, the longest ones as long as snout, 5.4 in head or 15.5 in length; scale formula 5–38–13; dorsal fin high, with VIII,15 (more usually VII,15 or 16 in paratypes), the spine slender, increasing in length posteriorly, the longest one 1.4 in head; the origin of fin about the length of the snout nearer tip of lower jaw than base of caudal; caudal fin only slightly forked; anal base nearly as long as that of dorsal, the fin with VI,18 rays, the spines graduated as in the dorsal, the last spine 1.57 in head, origin of fin under base of fifth dorsal spine and about equidistant from tip of lower jaw and base of caudal; ventral fins inserted under base of pectorals, the longest rays reaching opposite base of last anal spine; pectoral fins moderately long, 1.35 in head.

Color.—In alcohol, plain grayish green above and silvery below. Fins all pale, the dorsal, caudal, and anal with dusky punctulations, these most numerous distally on caudal.

Variability.—The specimens, being of nearly uniform size, vary little among themselves. The dorsal spines in the nine specimens at hand vary from 7 to 9—that is, six have 7 spines, two have 8, and one has 9 spines. The anal fin has 6 spines in eight specimens and 7 in the other. In color they vary in the number of dusky punctulations present on the vertical fins, some of the paratypes having the fins much darker than the type. The dark color, however, is not arranged in spots, as in *sparoides*, resembling *annularis* in this respect. Some of the paratypes have indications of pale spots on the caudal fin. Such spots are quite numerous and distinct on the caudal in specimens of about the same size in the related species and often are present, also, on the dorsal and anal fins.

Holotype.—No. 88381, United States National Museum, standard length 107, total length 142 millimeters; borrow pit near Money, August 14, 1925.

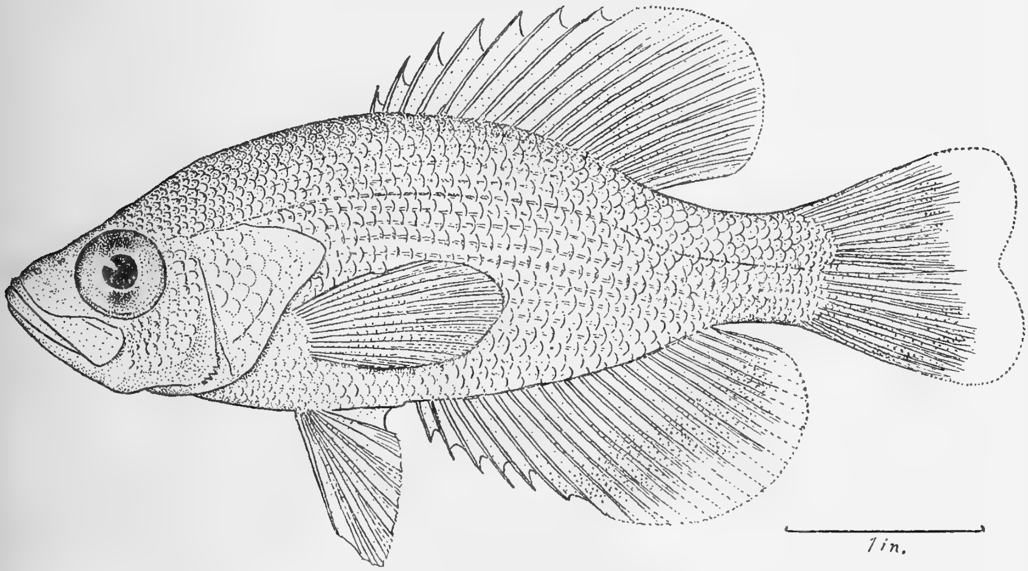

FIG. 8.—*Pomoxis barberi* n. sp. From a paratype

Paratypes.—Eight specimens from the type locality, all taken with the holotype.

The species is named for Dr. M. A. Barber, of the United States Public Health Service, who was engaged at Greenwood, Miss., in researches pertaining to malaria during the period when the present collection was made. Doctor Barber allowed the authors the free use of his laboratory and rendered other valuable aid.

This fish was found only in a borrow pit near Money in association with the black crappie, the white crappie being absent in this pond. This borrow pit had a length of about 200 feet, a width of about 30 feet, and the greatest depth of the water when the collection was made was about 5 feet. This pond, owing to its steep banks, the grayish clay soil, wave action, and the almost total absence of vegetation, was distinctly muddy. The golden shiner (*Notemigonus crysoleucas*) was the only other species present.

Four specimens of this species examined for food had fed mainly on copepods, ostracods, and some insects (principally back swimmers). The other species of crappie, when they had attained a length as great as the specimens of this form that were examined, usually had changed definitely to a fish and large insect diet, and the small crustaceans were ignored. Due to the scarcity of other foods, the fish probably continued to feed on the usual diet of the young. In obtaining this small food, they doubtless were aided by the long gill rakers and probably also by the very large eye. In eight specimens of the size of the black crappie, from the same body of

water, the alimentary canal was almost empty, as only a few insects (back swimmers), fragments of insects, and very few copepods and ostracods were found. Gambusia, one of the chief foods, locally, of the crappies, was absent in this pond.

32. **Chænobryttus gulosus** (Cuvier and Valenciennes)

WARMOUTH BASS; "SPOTTED BREAM"

Pomotis gulosus Cuvier and Valenciennes, Hist. Nat. Poiss., III, 1829, p. 498.

This is one of the common sunfishes at Greenwood, being exceeded in abundance only by the bluegill sunfish and by the white and black crappies. Its large mouth, the maxillary reaching past the middle of the eye, and the presence of teeth on the tongue distinguish it from related species occurring locally. In structure, the specimens at hand are fairly uniform, but in color there is much variation, both with age and among individuals of the same size. The young of about 3 inches and less in length have indefinite crossbars and no indications of dark spots on the scales that form longitudinal lines in adults. The dark stripes on the cheeks, usually quite evident and distinctive of the species, occasionally are wanting, and some individuals are much more definitely spotted than others.

The fin rays appear to be remarkably constant, for in 18 specimens examined, the dorsal fin had 10 spines in 15 specimens, 9 in 2 specimens, and 11 in only 1 specimen. The soft rays numbered 10 in all except one specimen, which had 11. In the same specimens the anal fin constantly had 3 spines and 9 or 10 soft rays.

The warmouth bass, although entirely carnivorous, has a notably varied diet, as shown by the contents of 18 stomachs, depending largely upon insects, however. The water boatman, Corixa, and whirligig beetles frequently are taken. Crustaceans, including the shrimp *Palæmonetes exilipes*, were next in frequency, with small fish less evident than either of these groups. The intestine approximates one-half the total length of the fish.

The reproductive period appears to be an extended one, as ripe fish were taken through June, July, and August. Sexual maturity seems to be reached at a comparatively small size, as a female only 85 millimeters in length contained well-developed roe. A fish 124 millimeters in total length contained approximately 4,000 nearly mature eggs, and larger individuals probably produce a proportionately larger number of eggs.

The 54 specimens in the collection range from 52 to 178 millimeters (2 to 7 inches) in total length and were collected at the following points: Borrow pit, Itta Bena Road; borrow pits, Grenada Road; slough at Browning; slough near Greenwood; Hadley or Allen Lake; borrow pit at Craigside; and in a drainage ditch at the Tallahatchie compress.

33. **Centrarchus macropterus** (Lacépède)

ROUND SUNFISH; "SUN PERCH"

Labrus macropterus Lacépède, Hist. Nat. Poiss., III, 1802, p. 447.

This little sunfish is quite unimportant as a food fish and is not very numerous locally. The numerous anal spines and rays (the usual number being VIII, 14), the short, round body, and the dark stripes along the rows of scales serve well to separate it from the other sunfishes.

Among the members of the sunfish family (Centrarchidæ) occurring in the present collection, the round sunfish is the best adapted for the utilization of the plankton crustaceans through its increased number of gill rakers. This species and the crappies were the only representatives of the family that made use of the minute crustaceans after the fish had reached the "adult stage," and under normal conditions the mature crappies apparently also ignored this type of food. The following table shows the wide variation in the number and length of the gill rakers that exists among the local representatives of this family.

Species	Number of gill rakers on lower limb of first arch	Per cent of diameter of eye occupied by longest gill rakers
Pomoxis annularis	19–22	66
Pomoxis spheroides	19–21	48
Pomoxis barberi	20–21	53
Centrarchus macropterus	25–27	61
Chænobryttus gulosus	6– 8	43
Apomotis cyanellus	8– 9	45
Lepomis megalotis	6	12
Lepomis humilis	9–10	30
Lepomis incisor	6–10	27
Lepomis heros	7	20
Micropterus salmoides	6– 7	74

Copepods, according to 10 specimens examined, constitute the principal food sought by the round sunfish; and small insects, including mosquito larvæ, also are taken frequently. Mosquito production probably is appreciably reduced in waters where this fish is numerous. The largest specimen (155 millimeters long) had fed largely upon immature mosquitoes, its stomach containing 20 anopheline and 6 culecine larvæ. This fish, however, was from a borrow pit at Money, where the mosquito-destroying minnow, Gambusia, was absent and the crappie was present in numbers sufficient to have reduced considerably the plankton Crustacea. The stomach is large, and the intestine is equal to one-third the total length of the fish.

A fish 120 millimeters in total length, taken June 20, contained approximately 5,600 nearly mature eggs, indicating that spawning probably takes place in the late spring and early summer. Ten specimens, ranging in length from 56 to 155 millimeters ($2\frac{1}{5}$ to $6\frac{1}{10}$ inches) were collected at the following localities: Borrow pit at Money; borrow pits on Grenada Road, slough near Greenwood; and borrow pit at Craigside.

34. **Apomotis cyanellus** (Rafinesque)

GREEN SUNFISH; "BREAM"; "SUN BREAM"

Lepomis cyanellus Rafinesque, Journal Physique, 1819, p. 420.

We follow Hubbs (1926, p. 72) in delimiting this species from Lepomis, although we are not convinced of the value of the further generic divisions that Mr. Hubbs has made. The large mouth and the well-developed supplemental maxillary bone in *cyanellus*, however, appear to be sufficiently important to permit of its generic distinction.

Locally, this sunfish is only a little less common than the warmouth. It is recognized by the large mouth (the maxillary reaching nearly or quite opposite the middle of the eye), the well-developed supplemental maxillary bone, and the toothless tongue, and in life it generally has wavy, blue-green lines on the cheeks and opercles.

Forbes and Richardson (1908, p. 250) examined the stomachs of eight specimens and found that more than one-third of the food consisted of fish and the remainder was composed of insects and crawfish. In Athens, Tex., the senior author selected a pond for propagating Gambusia to be used in antimosquito work. This small body of water was thought to be virtually free of fish. Gambusia did not thrive, however, and when the pond was seined it was found to contain a few green sunfish, which had the appearance of being well fed, and these fish, no doubt, had kept the Gambusia from multiplying. With this information at hand, it was rather surprising to find no fish at all among the foods eaten by 32 specimens examined, most of which were collected where small fish were numerous. Midge larvæ constituted the bulk of the food taken by the smaller sunfish; the water boatman Corixa occurred frequently in the ingested material of medium-sized fish or those from 30 to 60 millimeters in length; while whirligig beetles and larger beetles were favored by the full-grown fish. The stomach is large and the intestine is equal to one-half the total length of the fish.

The spawning season evidently is an extended one, as ripe or nearly ripe fish were taken in June, July, August, and September. A female 116 millimeters in length contained approximately 4,900 nearly mature eggs.

This species is represented in the collection by 43 specimens, ranging in length from 32 to 130 millimeters (1⅕ to 5⅛ inches). These were collected at the following localities: Borrow pit, Itta Bena Road; slough at Browning; slough near Greenwood; Pelucia Creek; and a borrow pit at Craigside.

35. **Lepomis incisor** (Cuvier and Valenciennes)

BLUE-GILL; "BLUE-NOSED BREAM"; "SHINER BREAM"

Pomotis incisor Cuvier and Valenciennes, Hist. Nat. Poiss., VII, 1831, p. 466.

Many specimens of this fish were preserved. A very large degree of variation with respect to the depth and the contour of the body, the length of the opercular flap, and color is evident among the specimens collected. The depth, for example, varied from 1.85 to 2.7 in standard length in 44 specimens measured. The opercular flap in several rather large specimens was notably produced, approaching, in that respect, the long-eared sunfish (*megalotis*). However, they have the longer gill rakers and the long, pointed pectorals of the bluegill. It so happens that these particular specimens were taken in a comparatively small body of water where both species occurred. Hubbs (1926, p. 71) has reported a number of combinations of hybrids. It is possible, although not probable, that the specimens with the long "ears" are hybrids. Other pronounced variations—as, for example, the differences in the depth of the body and in color—also occur among the specimens at hand, which are difficult to ascribe to the hybridization of local species and appear to be only variations within the species. It seems probable, therefore, that the difference in the development of the opercular flap, too, constitutes a variation within the species.

The marked variation in appearance among fish of this species may be said to be reflected in their feeding habits, as a wider range of diet appears to exist than for any of the other members of this family. According to the contents of 42 stomachs examined, this species utilizes considerable vegetation and appears to take much of its food from the substratum, but also feeds at the surface and among the plants. Filamentous algæ probably composed fully 50 per cent of the ingested material, appearing far too frequently to have been taken incidentally in the capture of other food. Quantities of pond snails, which seemed to be somewhat neglected by the other fish of the region, also had been taken. May-fly nymphs, midge larvæ, and a variety of other insects were commonly present in the stomachs. Minnows appear to be taken rarely, even by the full-grown bluegill, as only a single Gambusia was found among the 42 fish examined. The intestine was found to vary from 60 to 78 per cent of the total length of the fish.

This species appears to be the most prolific member of the sunfish family, as a female of 155 millimeters contained fully 12,000 eggs. It is said to be one of the most productive species and is recommended as being of considerable value for pondfish culture. The female appears to attain sexual maturity at an approximate total length of 90 millimeters. The spawning season evidently is an extended one, probably reaching its height during the early summer. Forbes and Richardson (1908, p. 259) report ripe fish for Illinois in May and June. No specimens taken in May are at hand. Fish with well-developed gonads, however, were taken in June, July, and August. Two hundred specimens, ranging in length from 14 to 172 millimeters (½ to 6¾ inches), were collected at the following localities: Borrow pits, Grenada Road; slough at Browning; slough at Money; Hadley or Allen Lake; and Roebuck Lake.

36. **Lepomis megalotis** (Rafinesque)

LONG-EARED SUNFISH; "BLUE-NOSE SUNFISH"; "NIGGER BREAM"

Ichthelis megalotis Rafinesque, Ichthyologia Ohiensis, 1820, p. 29.

This beautiful sunfish is not especially numerous locally. Adult males (120 millimeters long) are remarkable on account of a large nuchal hump. The species is recognized by the long, black, opercular flap, the moderate number (37 to 39) of scales in a lateral series, and the few (6) very short gill rakers on the first arch. Published accounts state that this species has no black spot at base of last rays of dorsal. Some of the specimens in the present collection, however, have an indication of such a spot.

The long-eared sunfish at Greenwood was found only in deep, clear waters, although at Augusta, Ga. (Hildebrand, 1923, p. 6), it occurred in densely overgrown brickyard ponds and also in certain borrow pits along the levee of the Savannah River. Its form does not indicate an especially active fish.

Midge larvæ constituted the bulk of the food found in eight specimens examined. The larvæ were supplemented by water boatmen (Corixa), with a small quantity of miscellaneous material. The intestine is equal to one-half the total length of the fish.

Spawning fish were taken in August and September. The eggs appear to be less numerous but of larger size than those of the other members of this family. A female 93 millimeters long contained approximately 1,000 nearly mature eggs that exceeded 1 millimeter in diameter. The sexes are readily distinguished in mature fish by the nuchal hump in the male.

Eleven specimens, ranging from 62 to 122 millimeters (2½ to 4⅘ inches) in total length, were collected from an artesian well overflow and a slough at Browning and from Roebuck Lake.

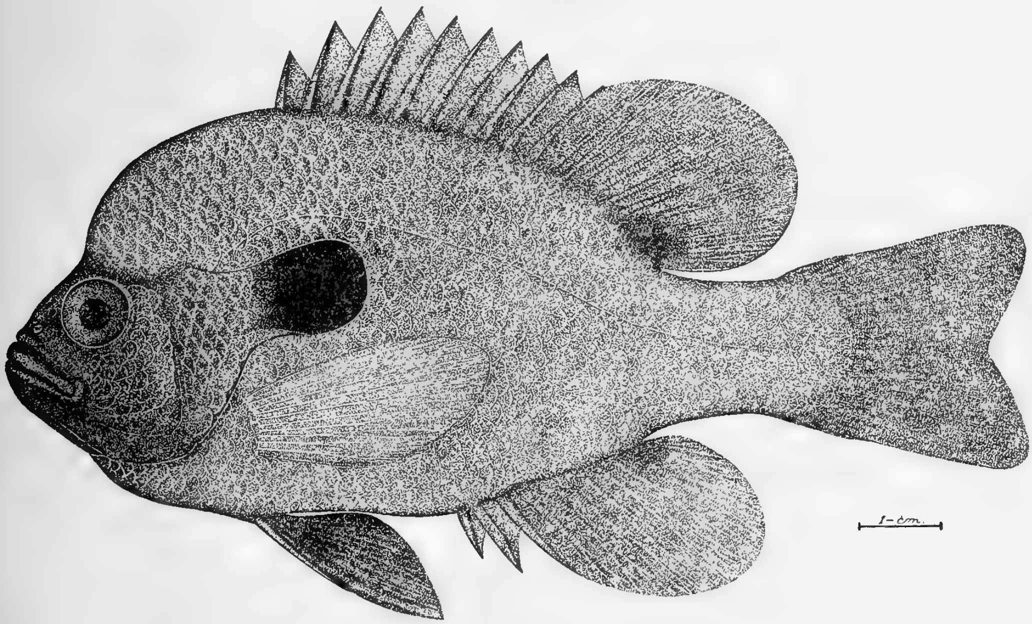

FIG. 9.—*Lepomis megalotis* (male)

37. **Lepomis symmetricus** Forbes

SYMMETRICAL SUNFISH

Lepomis symmetricus Forbes, in Jordan and Gilbert, Bull., U. S. Nat. Mus., XVI, 1883, p. 473.

We refer two small specimens, 51 and 56 millimeters (2 and 2⅕ inches) in length, to this species, both taken in a borrow pit on the Itta Bena Road. The fish probably is rare locally. This species appears to be characterized by the symmetrical body, both the dorsal and ventral outlines being about equally curved. Other distinctive characters are the rather long gill rakers, which are about nine in number and about half the length of the eye; the incomplete lateral line, with several pores missing on the arched portion, interrupted posteriorly and resumed on middle of side of caudal peduncle; the moderately long, pointed pectoral fins, reaching slightly beyond origin of anal; and the characteristic vertically elongate dark spots on the base of some of the scales (described in Forbes's original description as "vertical dark bars"). The specimens at hand have the caudal fin distinctly emarginate, as originally described by Forbes, not round, as shown in a drawing published by Evermann and Kendall (1894, Pl. XXXII, fig. 2) and republished by Jordan and Evermann (1896–1900, Pl. CLIX, fig. 424), based on a fish caught in Texas. The dorsal has X, 10 rays; anal III, 10; scales 33.

Immature insects, consisting of dragon-fly nymphs and midge larvæ, had been ingested by these fish. The length of the intestine is slightly over one-half the total length of the fish.

38. **Lepomis humilis** (Girard)

ORANGE-SPOTTED SUNFISH

Bryttus humilis Girard, Proc., Ac. Nat. Sci., Phila., 1857, p. 201.

The orange-spotted sunfish is one of the most brilliantly colored of our fresh-water fishes. It is so small in size that it has no commercial value, rarely exceeding a length of 3½ inches. It was not taken very often, and it does not seem to be very numerous locally, although it may have been overlooked at times because of its diminutive size.

An examination of the stomach contents of 15 individuals indicated a varied animal diet, consisting of the water boatman Corixa, midge larvæ, minnows, and minor quantities of miscellaneous materials. The intestine is from 43 to 45 per cent of the total length of the fish.

The season of reproduction evidently is an extended one, as ripe fish were found from June to September. They were less frequent, however, toward the latter part of this period. A fish of 60 millimeters contained 1,200 nearly ripe eggs, which was probably above the average, for two others of approximately the same length had only about one-half as many.

Twenty-four of these fish were collected, ranging in total length from 58 to 75 millimeters (2¼ to 3 inches). A borrow pit on the Itta Bena Road furnished most of these specimens, while others are from a borrow pit at Money and from Roebuck Lake.

39. **Lepomis heros** (Baird and Girard)

Pomotis heros Baird and Girard, Proc., Ac. Nat. Sci., Phila., 1854, p. 26.

We refer to this species a single specimen, 70 millimeters (2⅘ inches) in length, taken from a bayou at Sidon. The specimen in alcohol is rather plain brownish in color; base of scales slightly lighter, forming faint pale stripes along the rows of scales; opercular spot on bony part of opercle, with pale margin; pectoral fins are plain translucent; all the other fins are dusky with broad, pale margins. Dorsal formula is X, 11; anal III, 10; scales 37. The pectoral fins are rather short and not very pointed, reaching only opposite origin of anal, 1.4 in head. The gill rakers are very short, equaling only about one-fifth the length of the eye.

40. **Micropterus salmoides** (Lacépède)

LARGEMOUTH BLACK BASS

Labrus salmoides Lacépède, Hist. Nat. Poiss., IV, 1802, p. 716.

This bass is represented by 16 specimens, ranging from 30 to 400 millimeters (1⅕ to 15¾ inches) in length, all taken in a borrow pit containing a profuse growth of the primrose willow on the Greenwood–Itta Bena Road. The species does not appear to be abundant locally, and its congener, the small-mouth bass, was not seen. Its absence from the collection has little significance, however, as collecting operations were confined very largely to sluggish and standing water, an environment not frequented by the smallmouth bass.

An examination of the ingested material of 16 individuals showed a predominance of fish, supplemented by insects. Gambusia was preyed upon almost to the exclusion of other fish, probably because of its abundance in the particular pond where the bass were taken and because of its unwary disposition. *Fundulus kompi*, which simulates Gambusia in size and abounds in the pond where the bass were taken, had not been utilized. Six out of nine young bass, ranging in length from 30 to 47 millimeters, had eaten Gambusia, with May-fly nymphs, midge larvæ, and immature dragon flies less in evidence. The mature bass had taken aquatic beetles and crustaceans in addition to minnows.

Spawning is reported to take place in May and June in Illinois (Forbes and Richardson, 1908, p. 269). Seven adults collected early in June had passed the reproductive period.

41. **Elassoma zonatum** Jordan

PIGMY SUNFISH

Elassoma zonatum Jordan, Bull., U. S. Nat. Mus., X, 1877, p. 50.

A single specimen, 26 millimeters (1 inch) in length, occurs in the collection, and it is the only pigmy sunfish that was seen, although repeated attempts were made to capture more specimens in the overflow from an artesian well where this one was caught. The specimen was taken with a dipnet in company with Gambusia, in clear, closely shaded, and relatively cold shallow water The environment in which this fish usually is taken is favorable to mosquito breeding, and the fact that the individual at hand, when placed in an aquarium, readily fed on mosquito larvæ suggests that the species may be of value in localities where it is abundant in eradicating mosquito larvæ. Limited observations made by the senior author at Augusta, Ga., did not prove this to be the case, however, for he found relatively prolific breeding in a swamp well stocked with this fish, where, upon introducing Gambusia, mosquito production virtually ceased. It is entirely impossible, however, to know what the situation would have been in this swamp if the pigmy sunfish had not been present. Nevertheless, the fish may have taken a fair toll of "Wigglers."

Four pigmy sunfish collected at Augusta, Ga., had ingested the minute crustacean Cladocera and ostracods, with midge larvæ and insect fragments in about equal amounts. The intestinal tract equaled one-half the length of the fish, which ranged from 24 to 26 millimeters in total length.

42. **Morone interrupta** Gill

YELLOW BASS

Morone interrupta Gill, Proc., Ac. Nat. Sci., Phila., 1860, p. 118.

A single yellow bass, 168 millimeters (6⅗ inches) in length, was caught. This fish was seined in Roebuck Lake. It is reported in current works to be primarily a fish of the larger rivers and lakes. The species quite certainly does not occur in the smaller ponds and bayous locally.

Forbes and Richardson (1908, p. 322) report that "what little is known of its food indicates an insectivorous habit, adults feeding on aquatic larvæ, especially those of May flies, together with small crustaceans and terrestrial insects." The stomach of the specimen at hand contained portions of a small fish, a back swimmer, and a few plant fragments.

43. **Aplodinotus grunniens** Rafinesque

"GASPERGOU"; FRESH-WATER DRUM; SHEEPSHEAD

Aplodinotus grunniens Rafinesque, Journal Physique, 1819, p. 88.

This rather generally distributed species of the Mississippi Valley is represented by 14 specimens, ranging in length from 225 to 370 millimeters (8⅗ to 14¾ inches), and was taken only in a slough near Lake McIntire and in Roebuck Lake.

The gaspergou has a somewhat varied diet. According to the contents of 12 stomachs examined, it utilizes fish, mollusks, and insects in about equal amounts, with a minor quantity of miscellaneous materials, including vegetation and minute crustaceans. Vegetation, however, was present in only two stomachs and may have been taken incidentally in the capture of other foods. The intestine is that of a carnivorous fish, being only one-half as long as the fish.

In Illinois spawning is reported to take place during May and June (Forbes and Richardson, 1908, p. 325). Our specimens, taken during the summer, had the sexual organs in a collapsed condition.

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BIOLOGICAL SURVEY OF THE UPPER MISSISSIPPI RIVER, WITH SPECIAL REFERENCE TO POLLUTION

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CONTENTS

INTRODUCTION

HISTORICAL

The people of Minnesota and Wisconsin who are interested in the conservation of the fish life of the Upper Mississippi River have claimed that the abundance of fish in the river below Minneapolis and St. Paul is declining. Inasmuch as these people know that all the sewage and industrial waste from the Twin Cities (a combined population of over 600,000) and from South St. Paul, where packing plants are situated, are thrown into the Mississippi River without previous treatment, they attribute the apparent decrease in the abundance of fish to the effects of this sewage and trade waste. The conservationists of Wisconsin and Minnesota have demanded that these cities be prohibited from dumping untreated sewage into the river.

That this general belief in the decline in abundance of the fish in this region is not unfounded may be seen from Table 1, in which the yields of the various species of food fish in 1903 are compared with those in 1922. It is at once apparent that although the total yield has more than doubled in the 19-year interval, this increase is due almost entirely to the enormous catch of carp in the latter year, while the total yield of all other food fish has declined materially. The most desirable or popular species (such as black bass, crappie, pickerel, pike perches, sunfish, yellow perch, and white bass) disappeared entirely from the commercial catch in 1922, the yield of suckers was reduced greatly, and only those fishes that formerly were considered of less value, such as the buffalo, bowfin, and drum (aside from carp), have increased in yield.

TABLE 1.—*Products of the fisheries of the Mississippi River from Minneapolis to Winona in 1903 and 1922*

[From unpublished files of the Bureau of Fisheries]

Species	1903		1922	
	Pounds	*Value*	*Pounds*	*Value*
Food fish, except carp:				
Black bass	325	$26		
Buffalo fish	405, 245	10, 460	409, 310	$19, 841
Bowfin			21, 445	357
Catfish and bullheads	311, 149	17, 917	147, 016	13, 208
Crappie	19, 317	827		
Drum	283, 210	4, 988	429, 078	13, 529
Eels	6, 442	514	799	47
Paddlefish	202, 260	6, 142	16, 271	633
Pickerel	57, 525	2, 702		
Pike perch (wall-eyed)	35, 380	2, 028		
Pike perch (sauger)	14, 305	684		
Suckers	72, 060	1, 302	57, 434	1, 681
Sunfish	21, 400	490		
Sturgeon	14, 585	642	7, 753	1, 162
Yellow perch	300	14		
White bass	12, 545	442		
Total	1, 456, 048	49, 178	1, 089, 106	51, 073
Carp	473, 440	8, 969	3, 048, 332	101, 274
Grand total	1, 929, 488	58, 147	4, 137, 438	152, 347

There are few data to aid in estimating the rôle of the various factors (whether economic or biologic) in causing this decline in the fisheries. No doubt, changing market demand, legislation, overfishing, pollution, and changing physical environment all have affected the fisheries, and it is the object of this report to present new evidence bearing upon this important problem.

In 1925 a joint interim committee was appointed by the Legislatures of Wisconsin and Minnesota and instructed to obtain data on the general condition of the river and to present these data before the State legislatures in 1927. The interim committee decided that a biological survey should form a part of their general study of the Mississippi River and asked the United States Bureau of Fisheries to furnish an investigator to make this survey. The bureau agreed to do this on the condition that the field expenses of the bureau's investigator should be borne by the State governments.

Funds to the amount of $20,500 had been appropriated for the Mississippi River work by the conservation commissions of the two States, the Twin Cities, and the United States Public Health Service, of which $300 was made available for the work that the Bureau of Fisheries had been asked to do. This was supplemented by the bureau to the extent of about $1,000.

Because of the limited appropriation and time that could be devoted to field work, the results are not as complete as might be desired. Also, as most of the work was done after the heavy rains of last summer had begun, all of the results reported in this paper do not represent conditions as they exist when the river is at its lowest stage and when conditions are most critical.

AIM AND PLAN OF THE SURVEY

The aim of the biological survey was to determine whether the pollution from the Twin Cities is a factor in destroying aquatic life in the Upper Mississippi River; and if so, to ascertain, if possible, how far below these cities this pollution constitutes

such a factor. To answer these questions, the following general plan of action was drawn up:

1. Collect and preserve the animals of the bottom sediments.
2. Collect and preserve samples of surface scums, if present.
3. Collect and preserve net plankton; enumerate after completion of the field work.
4. Collect and preserve samples of strained water, to be centrifuged for the nannoplankton; enumerate as in 3.
5. Make notes on submergent and littoral vegetation and on the presence of coves or quiet water (source of plankton) along the shore.
6. Seine for fish. Preserve the small ones and take notes on the larger ones.
7. Obtain hydrometric data from the United States Geological Survey.
8. Obtain dissolved oxygen determinations from H. R. Crohurst, who is in charge of the United States Public Health Service's sanitary survey of the Upper Mississippi River.

It was decided that in order to obtain data most representative of conditions in the river it would be more advisable to visit each field station two or more times (until the funds were exhausted) and reduce the number of samples collected at each station to a minimum than to take a large number of samples at one time and visit each station once. Also, due to the limited funds, the field work was reduced to a minimum. All work ordinarily performed immediately in the field, but which could be postponed, was done at the University of Wisconsin.

ACKNOWLEDGMENTS

The writer wishes to express his gratitude to Dr. John Van Oosten, of the United States Bureau of Fisheries, for making the preliminary arrangements for the survey, for identifying the fishes, and for much valuable help rendered in the preparation of the report; to H. R. Crohurst, of the United States Public Health Service, for permission to use his data on dissolved oxygen; to Prof. Chancey Juday, of the Wisconsin Geological and Natural History Survey, for the loan of a centrifuge for the field work and for extending the privileges of his laboratory, where the plankton and the bottom samples were studied; and to the department of zoology, University of Michigan, for the loan of the plankton pump and the plankton net.

The writer is indebted also to Dr. Albert Mann, of the Smithsonian Institution, for the identification of the diatoms in some of the samples; and to Dr. V. Sterki, of New Philadelphia, Ohio, and C. F. Baker, of the Illinois Natural History Survey, for the identification of the mollusks.

The Minnesota Fish and Game Department furnished help and equipment for seining; the division of sanitation of the Minnesota State Board of Health furnished transportation to the station in the metropolitan area; and the biology department of the University of Minnesota furnished the writer an Ekman dredge and office space during the field work. The services of those responsible for these arrangements are greatly appreciated.

SAMPLING STATIONS

The stations selected for the taking of samples for the biological survey are the same as those that were selected for the sanitary survey by Mr. Crohurst. The locations of these stations are shown on the accompanying map. (Fig. 1.) Most of the stations are on the Mississippi River, of course, but in order to get some comparative data from unpolluted streams some sampling stations were chosen on the principal tributaries. The stations on the Mississippi River are so distributed that the data obtained represent conditions (1) before any sewage had been added, (2) after all the Minneapolis sewage had been added, (3) after all the St. Paul sewage

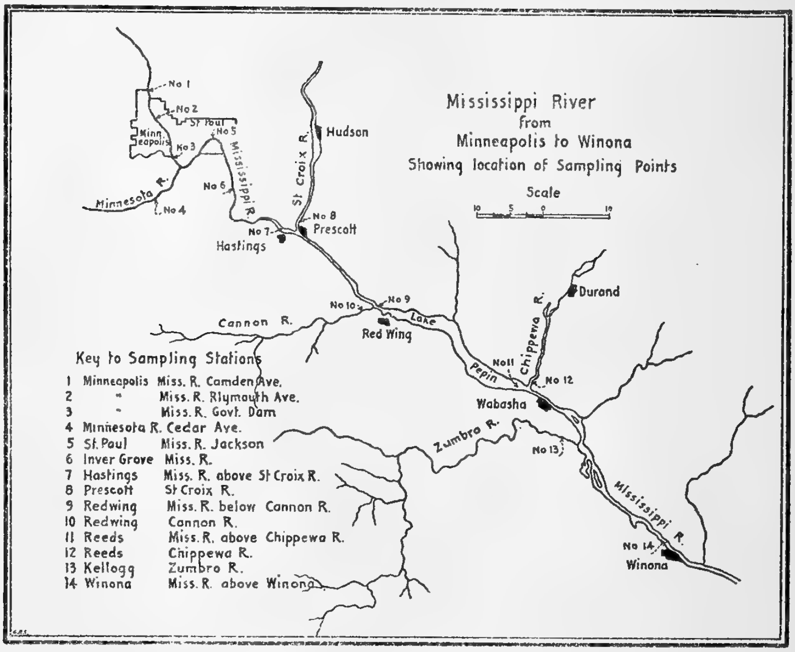

FIG. 1

had been added and one tributary had joined the river, (4) after the South St. Paul sewage had been added, and (5) at various distances below South St. Paul. In this way it should be possible to determine, approximately, the extent of the effect of the sewage from the Twin Cities and from South St. Paul. A brief summary of the distribution of the sampling stations follows:

Station No. 1 is on the Mississippi River above Minneapolis, at the Camden Power Plant, and represents the river before any sewage has entered it.

Station No. 2 is on the Mississippi River in the Minneapolis area, about 4 miles below No. 1. The river here is divided by an island into two branches. Considerable sewage has already entered the river above station No. 2. The right branch of the river receives additional sewage at this station and consequently is more polluted than the left branch.

Station No. 3 is above the Ford Dam, just below Minneapolis. By this time the river has received all the sewage that Minneapolis contributes. The dam here backs up the water, and as a result the current is very slack, so that most of the solid

material settles out on the bottom. According to information received from Mr. Elsberg, city engineer at Minneapolis, already there is a layer of sludge, 12 feet in depth, behind the dam, and this is accumulating at a rate of 12 inches each year.

Station No. 4 is on the Minnesota River, about 8 miles above its mouth and about 15 miles below the towns of Chaska and Shakopee. The joint population of these two towns is approximately 4,000.

Station No. 5 is on the Mississippi River, just below St. Paul, a distance of approximately 10 miles below station No. 3. By this time the river has received all the St. Paul sewage and also the discharge from the Minnesota River. The waters of the Minnesota River flow for about a mile over shallow rapids before entering the Mississippi River, and presumably enter the latter in a well-aerated condition. For the discharge of the Minnesota River see Table 2.

TABLE 2.—*Monthly mean discharge in second-feet for the period October, 1925, to October, 1926*

Date	Mississippi River at Elk River, Minn.	Minnesota River at the mouth	Mississippi River at St. Paul	St. Croix River at the mouth	Cannon River at the mouth	Chippewa River at the mouth	Zumbro River at the mouth
1925							
October	2,990	379	4,370	1,848	----------	3,600	----------
November	2,140	335	2,990	1,812	----------	3,906	----------
December	1,550	546	2,470	1,602	----------	3,416	----------
1926							
January	1,060	271	1,880	1,404	----------	2,458	----------
February	947	(1)	1,680	1,572	----------	2,276	----------
March	3,900	2,893	5,620	2,784	----------	5,712	----------
April	3,820	1,265	7,150	4,392	----------	12,768	----------
May	2,230	606	3,650	3,060	184	6,841	260
June	2,160	325	2,860	2,820	139	5,137	307
July	2,150	145	2,590	2,040	98	3,354	170
August	2,050	259	2,810	2,460	95	8,898	170
September	5,110	1,661	8,630	4,680	281	21,736	448
October	5,190	(1)	9,970	(1)	253	11,472	448

1 No record.

Station No. 6 is on the Mississippi River, about 3.5 miles below South St. Paul. The important change to occur between stations 5 and 6 is the addition of the sewage from South St. Paul, where packing plants are situated, and from a packing house situated across the river, opposite South St. Paul. Grease occurred commonly on the surface of the water when this station was visited.

Station No. 7 is on the Mississippi River at Hastings, about 37 miles below St. Paul. No sewage is added to the river between Hastings and station No. 6 at South St. Paul, yet a very marked change in the condition of the river takes place. At station No. 6 the water is relatively shallow and the current is fairly strong, so that there is little chance for much of the solid material to settle out. At Hastings (station No. 7) the current is rather slack, and consequently much of the solid material settles on the bottom. The water is much deeper, too, and therefore is less effectively aerated by winds.

Station No. 8 is at Prescott, Wis., on the St. Croix River, just above the junction of the St. Croix and the Mississippi Rivers.

Station No. 9 is on the Mississippi River at Red Wing, about 50 miles below St. Paul. By this time the river has received the waters of the St. Croix and the Cannon Rivers. The discharge for these rivers is given in Table 2.

Station No. 10 is on the Cannon River, a tributary that enters the Mississippi about 3 miles above Red Wing. The sampling station is some distance above the mouth of the river. The water at the station is clear, shallow, and flows very rapidly.

Station No. 11 is on the Mississippi River at the lower end of Lake Pepin, a short distance above the mouth of the Chippewa River. By the time the water reaches station No. 11 it has passed through Lake Pepin and has lost much of the solid material held in suspension. That Lake Pepin acts essentially as a settling basin is shown by the bottom deposits at the head of the lake and by the greater transparency of the water when it leaves the lake than when it enters it just below Red Wing.

Station No. 12 is on the Chippewa River where the latter enters the Mississippi at the lower end of Lake Pepin. (Lake Pepin is the result of the delta formed by the Chippewa across the bed of the Mississippi.) The discharge of the Chippewa is given in Table 1.

Station No. 13 is on the Zumbro River. This station was not visited during the biological survey.

Station No. 14 is on the Mississippi River just above Winona, about 110 miles below St. Paul. The station here was chosen above the city to avoid the effect of local pollution. The Mississippi River receives the discharge of the Zumbro River above this station. The hydrometric data for the Zumbro are given in Table 2.

HYDROMETRIC DATA

The hydrometric data shown in Table 2 were prepared from the gauging station records furnished by Mr. Soule, of the United States Geological Survey. The gauging stations on all the tributaries are at some distance above the mouth of the rivers; therefore, the data, as given in the station records, do not show the actual discharge at the mouth of the tributary. The figures in Table 2, however, do give the approximate mean discharge at the mouth of each tributary. Values are shown for each month of the period October, 1925, to October, 1926. The writer obtained these values by multiplying the mean, as given in the station records, by the ratio of the total drainage area of the tributary to the drainage area above the gauging station.

The hydrometric data, where they extend over the entire year, bring out the important fact that on each river there are two periods during the year when the discharge reaches a minimum. The first minimum occurs either in January or February and the second comes in July or August. With one exception—the Minnesota River—the winter minimum for the last year was lower than the summer minimum. From a biological standpoint these low-water stages may become very significant.

It is possible that the large amount of water during the high-water stages may so dilute the sewage and other wastes dumped into a river that their deleterious effect is reduced to a point where no harm results to fish and other aquatic life, but that during the low-water stages this pollution becomes so concentrated that all life is destroyed in the contaminated areas of the river. The periods of minimum discharge, then, may be limiting factors that determine whether fish or other aquatic organisms can survive in the polluted river.

TABLE 3.—*Mississippi River study—dissolved oxygen (parts per million) in August*

Date	Sta. 1, Camden	Sta. 2, Plymouth	Sta. 3, Dam	Sta. 4, Minnesota River	Sta. 5, Jackson Street	Sta. 6, Invergrove	Sta. 7, Hastings	Sta. 8, St. Croix River	Sta. 9, Red Wing	Sta. 10, Cannon River	Sta. 11, Reeds	Sta. 12, Chippewa River	Sta. 13, Zumbro River	Sta. 14, Winona
2	6.22	5.63	0.77	7.61	0.67	0.08	0.33	9.75	2.48	7.11	5.29	6.40	8.29	-------
3	6.27	5.62	.50	7.49	.41	.17	.10	9.09	2.30	7.50	4.95	7.23	8.10	7.80
4	6.00	5.23	.05	6.74	.90	1.20	.08	7.80	1.70	7.38	4.97	6.18	7.65	6.80
5	5.31	5.30	.00	5.73	1.00	.30	.20	7.53	1.90	7.61	5.31	5.68	8.20	7.51
6	6.24	5.69	.42	5.90	.02	.28	.05	7.00	1.82	7.13	5.85	6.30	8.64	-------
9	6.57	6.25	.00	5.49	.00	.00	.65	6.65	1.40	7.30	5.82	5.60	8.60	4.81
10	6.98	5.29	.00	4.91	.40	.00	.18	6.61	1.60	8.10	5.43	6.90	8.30	4.51
11	6.37	6.22	.00	5.45	.90	.31	.30	6.95	1.70	7.82	4.98	7.29	8.71	5.33
12	6.85	6.29	.05	5.60	.14	.00	.20	6.77	1.97	7.65	4.80	6.74	8.72	6.21
13	6.50	6.27	.10	5.41	.27	.00	.19	6.50	2.55	7.89	5.26	6.35	9.00	5.90
16	6.73	6.85	.00	7.19	.54	.05	1.45	5.72	1.67	7.33	4.78	6.36	7.76	6.45
17	6.55	6.30	.00	6.59	.87	.40	.09	6.43	1.12	8.02	5.64	6.57	7.59	6.63
18	6.62	5.63	.00	6.71	1.38	.43	.18	7.00	1.80	7.24	5.30	6.31	7.88	6.42
19	6.74	6.17	.00	5.77	.99	.17	.00	6.55	2.14	7.20	4.90	6.20	8.02	7.47
20	6.70	6.40	.00	5.14	.00	.25	.00	6.57	2.55	6.08	4.80	-------	7.30	6.10
23	6.82	6.41	3.67	4.18	2.52	1.60	1.20	6.93	1.55	7.12	5.50	5.20	7.77	6.34
24	6.63	6.32	2.04	3.93	2.40	1.97	.85	7.05	2.65	7.45	6.09	6.80	-------	4.80
25	6.89	6.20	1.06	3.80	1.52	.97	.40	6.40	2.88	7.82	5.61	5.68	7.91	5.59
26	6.90	6.32	.85	4.21	.42	.23	.32	6.68	3.09	7.30	6.41	6.05	7.64	4.50
27	7.05	6.55	3.79	6.30	1.20	1.20	.15	6.95	2.83	7.56	6.01	6.02	8.11	4.76
30	7.09	6.53	.71	5.61	1.58	.96	1.43	8.01	3.79	7.64	6.09	5.86	7.97	5.90
31	6.92	6.34	.71	5.58	.90	.70	.15	7.23	4.01	7.24	4.39	5.77	7.62	-------
Average	6.59	6.08	.67	5.70	.87	.51	.39	7.10	2.25	7.43	5.37	6.26	8.08	5.99
Average temperature	21.9	22.0	23.0	22.6	22.1	21.9	22.4	22.7	21.4	19.7	22.0	21.8	19.9	23.3
Per cent saturation	74.0	68.0	7.0	64.0	9.0	5.0	4.0	81.0	25.0	79.0	60.0	70.0	87.0	69.0

TABLE 4.—*Mississippi River study—dissolved oxygen (parts per million) in September*

Date	Sta. 1, Camden	Sta. 2, Plymouth	Sta. 3, Dam	Sta. 4, Minnesota River	Sta. 5, Jackson	Sta. 6, Invergrove	Sta. 7, Hastings	Sta. 8, St. Croix River	Sta. 9, Red Wing	Sta. 10, Cannon River	Sta. 11, Reeds	Sta. 12, Chippewa River	Sta. 13, Zumbro River	Sta. 14, Winona
1	6.99	6.09	0.42	6.10	0.44	0.40	0.10	7.19	4.30	7.56	4.54	5.81	8.71	7.17
2	6.75	5.98	.00	5.39	.51	.75	.10	8.72	2.89	7.42	4.70	5.67	8.10	6.93
3	6.50	6.04	.55	5.15	1.31	2.10	.29	8.70	3.41	8.69	5.30	5.81	8.31	6.69
7	7.79	7.12	5.59	4.81	4.43	3.81	2.70	7.11	2.89	8.31	6.11	6.01	8.78	7.03
8	7.62	7.49	4.61	6.68	4.06	3.01	2.50	6.98	4.43	7.80	6.58	6.79	8.04	-------
9	7.69	7.40	4.20	5.97	3.70	2.92	1.60	-------	3.43	8.27	7.15	6.85	7.81	5.39
10	7.81	7.49	4.06	6.99	4.39	3.43	1.01	7.14	3.00	8.71	6.68	7.61	9.13	7.03
13	8.43	8.74	6.66	7.01	6.18	5.79	3.69	7.50	3.72	9.66	6.80	7.20	9.50	7.31
14	8.30	7.95	5.94	6.86	6.02	6.08	3.95	7.62	4.37	9.01	6.80	7.42	9.10	7.07
15	8.01	7.88	5.25	7.36	6.15	6.20	3.09	7.23	4.16	8.81	6.51	6.90	8.69	7.30
16	7.70	7.61	5.48	8.40	5.73	5.54	3.50	-------	3.43	8.62	7.25	6.63	8.94	7.11
17	7.74	7.31	5.80	8.62	5.68	5.68	3.13	6.97	4.39	-------	6.24	6.47	9.03	8.05
20	7.79	7.36	6.44	6.38	6.46	6.19	4.20	7.27	3.93	7.43	7.79	7.41	8.13	-------
21	8.00	7.49	5.94	6.98	6.14	5.92	4.45	6.53	4.78	7.72	7.08	7.09	7.34	7.62
22	7.68	7.62	6.09	5.30	5.91	6.02	4.12	7.01	4.27	7.69	6.92	6.55	7.53	-------
23	7.76	7.40	6.01	6.30	5.88	5.31	4.20	7.08	4.49	8.15	7.38	6.38	7.90	7.69
24	8.05	7.82	6.33	5.55	-------	5.81	4.30	7.40	5.20	8.80	7.80	6.60	8.95	-------
27	9.10	8.94	8.52	7.59	8.14	7.53	5.92	7.30	5.08	9.58	8.32	8.70	9.60	8.11
28	8.87	8.81	7.33	8.25	7.32	7.31	6.14	-------	6.44	9.41	8.30	8.61	10.18	7.40
29	8.95	8.74	7.42	8.28	7.62	7.41	5.68	7.90	5.10	9.36	8.39	7.99	9.63	-------
30	9.62	9.31	8.10	8.59	7.70	7.52	5.87	7.27	6.07	9.33	8.71	8.58	9.58	8.85
Average	7.96	7.65	5.27	6.79	4.94	4.99	3.36	7.38	4.27	8.52	6.92	7.00	8.71	7.30
Average temperature	16.4	16.1	16.8	17.2	16.5	16.4	17.4	18.8	18.7	18.5	19.3	18.2	16.9	21.7
Per cent saturation	80.0	79.0	53.0	70.0	50.0	50.0	35.0	78.0	44.0	90.0	74.0	73.0	89.0	82.0

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DISSOLVED OXYGEN

All organisms require oxygen for the maintenance of life. Aquatic animals, with the exception of air breathers, depend for their oxygen supply upon the oxygen dissolved in the water. The amount of dissolved oxygen, therefore, furnishes one good index as to the suitability of a body of water to support life. It is possible, of course, to find waters with a high dissolved oxygen content that are unsuitable for living organisms. This is often the case when waters are polluted by mineral acids, bases, and salts, or by other chemical ingredients that act as specific poisons. However, in a body of flowing water such as the Mississippi River, which does not stratify and stagnate, the presence of oxygen at normal temperatures in minimal quantities is an indication of pollution.

Tables 3 and 4 give the results of dissolved oxygen determinations made by Mr. Crohurst for the months of August and September, 1926. These tables also give the average monthly temperatures of the water at the various field stations. From these data the average percentage of saturation for each month was calculated. For some purposes it is more expedient to express oxygen content in terms of the degree of saturation than in terms of the absolute amount.

Table 3 shows that during August the amount of dissolved oxygen was far greater at some stations than at others. Dissolved oxygen was present in fairly large amounts at all the stations on the tributaries (the average ranged from 5.70 to 8.08 parts per million, or 64 to 87 per cent of saturation) as well as at stations 1, 2, 11, and 14 (average ranged from 5.37 to 6.59 parts per million, or 60 to 74 per cent of saturation) on the Mississippi River. The waters at stations 3, 5, 6, and 7 on the Mississippi River (average ranged from 0.39 to 0.87 parts per million, or 4 to 9 per cent of saturation) contain very small amounts of dissolved oxygen, sometimes a trace only, or none at all. At station No. 9 (average = 2.25 parts per million, or 25 per cent of saturation) conditions with respect to dissolved oxygen are much better than they are at stations 3, 5, 6, and 7, but are not nearly as good as they are at stations 1, 2, 11, and 14. The monthly average at No. 9 probably has been raised through the heavy rains that fell during the latter part of the month. Table 4 shows that a marked improvement with respect to dissolved oxygen occurred at stations 3, 5, 6, and 7 after the first week in September. This improvement undoubtedly is due to the cooler weather and to the large increase in the volume of water in the river, the results of heavy rains.

The data in Tables 3 and 4, then, show the following facts:

1. During August and the first week of September, 1926, the dissolved oxygen content is decidedly less in that section of the Mississippi River that extends from station No. 2, at the beginning of the metropolitan area, to station No. 9, at the head of Lake Pepin (a distance of approximately 64 miles), than it is above or below this section or in the tributary waters. The tributaries and the Mississippi River above the Twin Cities obviously are not polluted by the sewage of Minneapolis and St. Paul. As stated above (p. 142), many of the suspended materials in the Mississippi waters settle at the head of Lake Pepin, which virtually is a settling basin. The water at stations in and below this lake (Nos. 11 and 14), then, should be comparatively free from any sewage that may be carried down to station No. 9; and

if this sewage is the primary factor involved in the depletion of dissolved oxygen in the upper Mississippi River, the oxygen content at stations 11 and 14 should show a distinct increase above that of station No. 9. The data show that this increase does occur. The decrease in the dissolved-oxygen supply of the Mississippi waters in the section described above is unquestionably due to the pollution of the river.

2. The data in Table 4 show that the heavy rains in the fall quickly increase the oxygen content of the polluted waters and eventually restore the normal supply even in the most polluted areas. (See data for September 27 to 30, Table 4.)

BOTTOM FAUNA

RELATIONSHIP OF BOTTOM FAUNA AND POLLUTION

Next to a thorough chemical study, a study of the bottom-dwelling organisms is perhaps the best criterion to be used in determining whether or not a given body of water is polluted. We know with a fair degree of accuracy what kind of organisms are indicative of grossly polluted waters and what organisms can be expected only in fairly clean waters. Of course, numbers of individuals play quite as important a part here as does the species or kind of animals. The presence of a few specimens of the worms Limnodrilus and Tubifex, or of the mollusk *Musculium transversum,* or of the red midge *Chironomus plumosus* is not significant. Studies in the Illinois River, however, have shown that the presence of a large number of these organisms is indicative of pollution. Again, it has been shown that the presence of the larvæ of the caddis fly and the sand fly and the nymph of the May fly may be taken as evidence that the water inhabited by them is not polluted to any considerable extent. These facts are based on many years of study of a biological and a chemical nature by Forbes, Richardson, Shelford, Thompson, and others.

METHODS

Samples for the study of the bottom-dwelling forms were taken by means of a small Ekman dredge. An attempt was made to obtain on each trip at least two samples at each field station—one near the shore and the other in the channel. At times it was impossible to get a sample in the channel because of the nature of the bottom and the strength of the current. The small Ekman dredge works best in soft mud or in places where a great deal of organic débris has settled out. On hard, gravelly bottom it is not very effective; it is too light to go into the bottom to any appreciable extent and, also, the gravel gets behind the jaws and prevents them from closing. A record was kept of the number of hauls taken at each station. Then, either the entire sample or a known portion of it was preserved in 4 per cent formaldehyde.

In the laboratory, the samples were placed in a strainer having a bottom of bolting cloth of 50 meshes per square centimeter. In this strainer the samples were washed with tap water until they were free from mud. The coarse sand and organic débris, as well as the macroscopic animals, were retained in the strainer. After the removal of the mud the sample was placed in a dish and the animals were separated and counted. From the number of each kind of animal obtained from the sample, the area of the dredge, and the number of hauls made for the sample, the number of animals per square yard was calculated. In some cases the volume of the sample

was ascertained before and after straining in order to obtain some information as to the relative amount of coarse organic débris, pieces of plants, chips of wood, and in some instances garbage, gravel, and fine mud. The partial results of these determinations are shown in Table 6.

RESULTS AND DISCUSSION

The abundance of the bottom-dwelling animals is expressed in numbers per square yard, and the data are shown in Table 5. The table shows that there is a marked difference in the kinds and numbers of animals that occur at the different stations.

TABLE 5.—*Bottom fauna, animals per square yard, 1926*

[S=shore; C=channel]

Bottom fauna	Sta. 1, Aug. 14	Sta. 1, Sept. 7	Sta. 2, Aug. 14	Sta. 2, Sept. 7	Biology Bldg., Sept. 10	Lake St. Bridge, Sept. 13	Sta. 3, Sept. 8	Sta. 3, Sept. 8	On stones Sta. 3, Sept. 8	Sta. 4, Aug. 17	Sta. 5–S, Aug. 17
Dragon fly nymphs	36										
May fly nymphs		144									
Caddis fly larvæ		72									
Simulium		396									
Tubificidae	252			15,120	364,000	118,000	10,800	632	[1] 6,159	108	11,970
Chironomus	36	108	36					36	5		144
Hyalella	36										
Planaria		72									
Campeloma rufum				1,600							
Sphærium sp	108										
S. notatum				54							
Musculium near transversum							85				1,620
M. near truncatum						500					
Musculium sp						72					
Beetle larvæ	72										
Leeches						72		14	1		

Bottom fauna	Sta. 5–S, Sept. 15	Jackson Street Bridge, Sept. 27	Sta. 6–S, Aug. 18	Lefts, Sta. 6–S, Sept. 16	Rights, Sta. 6–S, Sept. 16	Sta. 7–S, Aug. 18	Sta. 7–S, Sept. 16	Sta. 7–C, Aug. 18	Sta. 7–C, Sept. 16	On stones, Sta. 8, Aug. 19	Sta. 8, Sept. 16
May fly nymphs										([2])	72
Tubificidæ	5,832	2,880	2,520	75,400	10,260	103,860	126,000	31,680	65,400		360
Chironomus	3,240	144									
Hyalella											3,240
Planaria											432
Pleurocera acuta										9	
Physa sp										11	
Campeloma rufum										1	36
Heliosoma trivolvis										2	
Mussels											18
Leeches	1,157	36						720			167

Bottom fauna	Sta. 9–S, Aug. 27	Sta. 9–S, Sept. 17	Sta. 9–C, Aug. 27	Sta. 9–C, Sept. 17	Sta. 10, Aug. 27	Sta. 11–S, Aug. 28	Sta. 11–S, Sept. 18	Sta. 11–C, Aug. 28	Sta. 11–C, Sept. 18	Sta. 14–S, Aug. 31	Sta. 14–S, Sept. 19
Dragon fly nymphs		48		48		18	12				
Damsel fly nymphs						54	12			36	
May fly nymphs					([3])					144	342
Caddis fly larvæ				12							
Tubificidæ	1,980	2,900	36	240				18	900		180
Chironomus	18					54	36	36		684	
Hyalella	1,260	3,000		24		3,600	3,200	18		144	
Asellus	54							18			
Planaria						36		36			
Pleurocera acuta						90	18	90	18		
Campeloma integrum	252	288	108	72						36	18
Anodonta imbecillis		48									
Musculium near transversum				2,520							
M. transversum	1,600										
Heliosoma trivolvis	90										
Leeches	2,295	1,776	684	492			12	180		36	

[1] Per liter. [2] Many. [3] Some.

TABLE 6.—*Relative amounts of residue in bottom samples, expressed in cubic centimeters and per cent, the nature of the residue, and the character of the predominating animals of the bottom fauna*

[S=shore; C=channel]

Station	Sample, cubic centimeters, before straining	Sample, cubic centimeters, after straining	Per cent	Nature of residue after the animals were removed	Predominating animals in bottom samples
1				Clean, coarse sand	Clean-water forms.
2	450	290	64	Garbage	Tubificidæ and *Campeloma rufum.*
3	400	300	75	Cinders; coarse garbage; chips of wood	Tubificidæ.
5				Coarse organic débris; sand	Tubificidæ and bivalves.
6	310	120	38	Little organic débris; pieces of fat and gray sand	Tubificidæ.
7-C	200	150	75	Organic débris	Do.
8	250	50	20	Aquatic plants; cinders; but mostly sand	Clean-water forms.
9	400	350	87	Shells of bivalves	Leeches.
9-S	200	175	87	Aquatic plants; broken-up leaves	Leeches, Hyalella, and Tubificidæ.
11-S				Sand and aquatic plants	Hyalella.
14-S	300	230	77	Mostly coarse gravel; little organic débris	Aquatic insects (clean-water forms).

The sample taken near the right bank of the river, at station No. 1, showed that each square yard of the bottom contained 252 Tubificidæ, 36 midge larvæ (Chironomus—not the red midge), 36 dragon fly nymphs, 36 specimens of *Hyalella knickerbockeri,* and 108 individuals of Sphærium sp. ? (a small bivalve). The second sample was taken in the channel near the left bank of the river. Here the substratum consists of pure sand with a few scattered plants. In the channel the Tubificidæ are absent entirely. Midge larvæ are more numerous (108 specimens per square yard) here than near shore. A number (72 per square yard) of beetle larvæ (Elateridæ) occur in the channel, but these are not aquatic. Associated with the above forms were four species of animals known to prefer clean, running water. These are Planaria, caddis fly larvæ, larvæ and pupæ of the sand fly (Simulium sp. ?), and May fly nymphs. The residue of the strained sample, after the removal of the animals, consisted of pure sand.

At station No. 2 the first mud sample was taken in the left branch of the channel at the same place where the seine hauls for fish were made. The bottom here is fairly clean and solid. The only animal taken in this sample was a midge larvæ. The second sample was taken some 50 yards below a sewer outlet in the right branch of the river. The difference in these two samples demonstrates the effect of sewage on bottom fauna quite clearly. In the first sample there were only 36 midge larvæ per square yard, but in the second there were 15,120 Tubificidæ, 1,600 snails (*Campeloma rufum*), and 54 bivalves (*Sphærium notatum*) per square yard. The residue of the second sample, after straining and the removal of the organisms, consisted of garbage. The results from this second sample are not representative of a cross-section of the river at this place. In the channel of the right branch and along the left branch of the river the bottom is fairly clean. However, as mentioned before, it demonstrates the effect of sewage.

No reference has been found in the literature to the tolerance of *Campeloma rufum* in polluted waters, but the above data indicate that very likely it is one of the more tolerant forms. *Campeloma subsolidum* is classed by Richardson (1925) as one of the less tolerant snails.

Four bottom samples were taken at places other than those designated as stations 1 to 14. One of these samples was taken immediately below the Washington Avenue bridge, directly opposite the university campus. The sample contained no life of any sort; it had a tarry odor and contained tar. The tar was introduced into the river by a gas plant situated a short distance above the Washington Avenue bridge. The waste from this plant undoubtedly explains the absence of all bottom dwelling animals. The heavy tar settles to the bottom and the lighter tar and other oily substances form a film on the surface. This surface film was quite pronounced on some days, both as to extent and thickness. Shelford (1917) has demonstrated the detrimental effect of gas-plant waste on fish. He says, in part: "Illuminating gas, gas liquor, and 31 out of 34 representatives of the chief group of compounds found in gas and gas liquor are very toxic to fishes." In England it has been demonstrated that washings from tarred roads are killing fish in some streams. (Committee on pollution, 1924–25.)

Another sample was taken near shore behind the animal biology building at the University of Minnesota. Two dredge hauls here yielded a sample of 4 liters; 75 cubic centimeters of this sample yielded 385 tubificid worms. This gives the enormous number of 364,000 Tubificidæ per square yard. The sample contained a great deal of fine mud and a considerable amount of coarse organic débris.

A third sample[1] was taken at the Lake Street bridge, about 1 mile below the spot where the last-mentioned sample was taken. The sample was taken in mid-stream and consisted largely of dead aquatic plants. It is the writer's opinion that the dredge did not penetrate into the real sludge on account of these weeds. From this sample 3,300 worms were removed. This gives a tubificid population of 118,000 individuals per square yard. The data also showed that each square yard contained 500 *Musculium* near *truncatum*, 72 Musculium (species unknown), and 72 leeches.[2] The bivalves taken were gravid. *Musculium truncatum* is classified as unusually tolerant by Richardson (1925).

At station No. 3, one sample was taken just above the Ford Dam, where the water is taken into the power station. There is considerable current in this part of the river and, therefore, the bottom is kept fairly clean. (Behind the dam proper conditions are entirely different (p. 141), but no samples were obtained there.) The 5 dredge hauls made along shore here yielded a 200-cubic centimeter sample, which, after straining, left a residue of 60 cubic centimeters. Besides the fauna, the residue was composed of sand plus a small amount of organic débris. Each square yard of bottom here contained 632 tubificids, 36 midge larvæ, and 14 leeches. Mud scraped from stones at station No. 3 contained 6,159 Tubificidæ per liter.

A third sample at station No. 3 was taken a short distance above the Ford Dam. The water here is about 35 feet deep in mid-channel, and the current is very slack when the water is not going through the wheels or over the dam. One haul here yielded a 400-cubic centimeter sample. The entire sample was strained, leaving a residue of 300 cubic centimeters. In addition to the fauna, the residue consisted of coarse organic débris suggestive of garbage, cinders, and many chips of wood. The

[1] The last three samples were taken between stations 2 and 3.

[2] The vast majority of the leeches were *Helobdella stagnalis* Blanchard. In this connection, the author wishes to acknowledge the services of Dr. J. Percy Moore, whose report on leeches was of great help in identifying the species found.

odor of the sample was distinctly foul and oily. The sample yielded 10,800 Tubificidæ and 85 specimens of *Musculium* near *transversum* and near *truncatum* per square yard.

The sample from the Minnesota River (station No. 4) yielded 108 Tubificidæ per square yard. Besides the organisms, a few grains of coarse sand were left in the strainer after the sample had been washed with tap water.

The last of the extra samples (see p. 148) was taken just above the Jackson Street Bridge, about one-half mile above station No. 5. A sample taken here on September 27 yielded 2,880 Tubificidæ, 144 Chironomus larvæ, and 36 leeches per square yard. This sample was taken partly along shore and partly in the channel.

At station No. 5 no bottom samples were obtained in the channel. The current was rather swift in the channel, and with the prevailing high waters its bottom was kept fairly clean from deposits.

The first sample taken along shore at station No. 5 consisted (besides the animals it contained) of coarse sand and a considerable amount of organic débris. The sample yielded 144 midge larvæ, 11,970 Tubificidæ, and 1,620 bivalves per square yard. The bivalves were made up of *Musculium* near *transversum, M.* near *truncatum,* and a few specimens of Pisidium. This is the first instance where these bivalves occur in such large numbers. Both the worms and the bivalves are an indication of pollution.

The second sample at No. 5 was taken in a slough permanently connected with the river. The reason for taking the sample in the slough was the fact that what was shore when the first sample was taken (August 17) was now (September 15) channel, and the bottom deposits had been carried away. This slough now formed a part of the shore. One dredge haul here yielded a sample of 700 cubic centimeters, 200 cubic centimeters of which were strained. In addition to the fauna, the residue of 50 cubic centimeters consisted of sand and Elodea. Each square yard of the bottom here contained 3,240 midge larvæ, 5,832 Tubificidæ, and 1,157 leeches.

The first bottom sample at station No. 6 was taken near shore in shallow, swiftly flowing water. The sample showed that each square yard of the bottom contained 2,520 Tubificidæ. The residue left after the sample had been washed consisted of coarse sand. In September, two bottom samples were taken a little farther downstream, where the strength of the current was reduced greatly by wing dams. One sample was taken near the left bank of the river and the other near the right bank. The former yielded 75,400 Tubificidæ per square yard and the latter 10,260. The sample from the right bank contained several pieces of fat, a little organic débris, and gray sand.

The condition of the bottom at station No. 7 is the worst that was met below Minneapolis. When the first visit to this station was made (August 18), gas bubbles (nature of gas not known) were rising continually, not only along the shore but also in the channel. From time to time large pieces of solid material came to the surface. As mentioned above (p. 141), the current here is rather slack, and this facilitates the settling out of the solid materials. The organic materials presumably ferment at the bottom, partly, perhaps, under anærobic conditions. The gases resulting from these fermentations undoubtedly are responsible for raising large masses of solids to the surface. The bottom samples taken on August 18 consisted (besides the animals they contained) entirely of organic débris. The sample had an extremely foul odor.

That there was a considerable layer of this organic débris was shown by the fact that the dredge was filled to the top. Alongshore there was less of this organic débris but more fine mud. When this station was revisited on September 16, conditions were very much improved. Much of the bottom deposit in the channel had disappeared (result of heavy rains). No solid masses were seen rising to the top, but gas bubbles still were very much in evidence along the shore. The bottom animals here are mostly tubificids. In August there were 103,860 per square yard near shore and 31,680 per square yard in the channel. Associated with the tubificids in the channel were 720 leeches per square yard. On September 16 there were 126,000 tubificids per square yard along shore and 65,400 per square yard in the channel. The difference in the number of Tubificidæ in the August and the September samples is not significant, perhaps, and may be due to natural fluctuation or local variations in abundance.

Conditions at station No. 8 (in the St. Croix River) are in marked contrast to the conditions prevailing at No. 7. The first sample taken near shore on the Wisconsin side consisted of pure sand only; but along the shore, on stones, May fly nymphs and the snails, *Pleurocera acuta* and Physa sp.?, were abundant. One specimen of *Campeloma rufum* and two of *Heliosoma trivolvis* also were taken. It will be recalled that *Campeloma rufum* was very abundant near a sewer outlet at No. 2.

The second sample at No. 8 was taken just off the peninsula (on the St. Croix side), where the waters of the Mississippi and the St. Croix Rivers meet. In addition to the bottom fauna, the sample consisted of fine sand, cinders, pebbles, and live aquatic vegetation. Each square yard of the bottom here contained 360 Tubificidæ, 167 leeches, 3,240 Hyalella, 432 Planaria, and 72 May fly nymphs. One large mussel and a few specimens of *Campeloma rufum* also were taken.

The samples of stations No. 7 and No. 8 illustrate clearly the effect of environmental conditions on the character of the fauna. Whereas the badly polluted waters at station No. 7 contained large numbers of Tubificidæ and leeches only, the less polluted waters at station No. 8 contained not only these forms (which, however, were much reduced in numbers) but also *Hyalella knickerbockeri* (a crustacean), Planaria, May fly nymphs, a mussel, and the following snails: *Campeloma rufum, Pleurocera acuta,* Physa sp.?, and *Heliosoma trivolvis.* Planaria and the May fly nymphs are definitely known to be clean-water forms.

The bulk of the sample taken in the channel at station No. 9 in August consisted of empty shells of the small bivalve (*Musculium transversum*). The animals taken with these shells were as follows: 36 Tubificidæ, 684 leeches, and 108 specimens of *Campeloma integrum* per square yard. On September 17 three dredge hauls in the channel here yielded 65 cubic centimeters of empty shells. The sample also contained 240 Tubificidæ, 2,520 individuals of *Musculium* near *transversum,* 492 leeches, 72 *Campeloma integrum,* 24 Hyalella, 12 Caddis fly larvæ, and 48 dragon fly nymphs per square yard. In the shore sample there were in August, in each square yard of bottom, 1,980 Tubificidæ, 18 chironomid larvæ, 1,260 Hyalella, 54 specimens of Asellus, 252 *Campeloma integrum,* 1,600 *Musculium transversum,* 90 *Heliosoma trivolvis,* and 2,295 leeches. In September the shore samples gave 48 dragon fly nymphs, 2,900 Tubificidæ, 3,000 Hyalella, 288 *Campeloma integrum,* 48 specimens of *Anodonta imbecillis,* and 1,776 leeches per square yard. The much smaller number

of Tubificidæ here, as compared with the number occurring at station No. 7, the presence of dragon fly nymphs, Caddis fly larvæ, Asellus, and the large number of Hyalella, may all be considered as marking a stage of transition in the conditions of the Mississippi River. Table 5 shows that dragon fly nymphs, Caddis fly larvæ, and Hyalella occurred at station No. 1 on the Mississippi River, and that these forms have not been taken at any of the stations on the Mississippi River between stations 1 and 9. In Europe, the presence of Asellus is taken as the first sign of improvement in a polluted stream (Wundsch, 1926).

The bottom sample taken at station No. 10 consisted of coarse sand. No animals were taken in this sample, but some May fly nymphs were seen clinging to the undersurface of stones. This suggests that the Cannon River is not polluted at this station.

Bottom samples from station No. 11, on the Mississippi River, indicate further improvement in the conditions of the river. Tubificidæ are absent entirely from the samples taken along the left shore. In August the shore sample gave 18 dragon fly nymphs, 54 damsel fly nymphs, 54 larvæ of Chironomus, 3,600 Hyalella, 36 Planaria, and 90 *Pleurocera acuta* per square yard. In September there were, near shore, 12 dragon fly nymphs, 12 damsel fly nymphs, 36 larvæ of Chironomus, 3,200 individuals of Hyalella, 18 *Pleurocera acuta*, and 12 leeches per square yard. In August the bottom fauna of the channel consisted of 18 Tubificidæ, 36 larvæ of Chironomus, 18 Hyalella, 18 individuals of Asellus, 36 Planaria, 90 *Pleurocera acuta*, and 180 leeches; and in September, of 900 Tubificidæ and 18 *P. acuta* per square yard.

Due to a lack of proper equipment, no bottom samples could be obtained at station No. 12.

Station No. 13, on the Zumbro River, was not visited.

The bottom samples of station No. 14 were all taken near shore. The samples for August showed that each yard of bottom contained 36 damsel fly nymphs, 144 individuals of Hyalella, 144 May fly nymphs, 684 larvæ of Chironomus, 36 individuals of *Campeloma integrum*, and 36 leeches. In the September samples there were 342 May fly nymphs, 180 Tubificidæ, and 18 specimens of *Campeloma integrum* per square yard. The May fly nymphs are the most significant element in the bottom fauna at station No. 14. They have not been found at any other station in the Mississippi River except at station No. 1, which is above Minneapolis. May fly nymphs also were taken in the St. Croix and Cannon Rivers. The presence of May fly nymphs at station No. 14 may be taken as an indication that conditions in the river above Winona are fairly good and probably are comparable with conditions as they exist at station No. 1 above Minneapolis.

A study of the bottom samples (Table 5) shows that the clean-water animals were taken at stations 1, 8, 9, 10, 11, and 14 only, and that at these stations and at No. 4 the tolerant forms, in general, were least abundant. The study shows, further, that all the bottom samples taken from the Mississippi River between stations 1 and 9, except one of those taken between stations 2 and 3 in the metropolitan area, which took no animals at all, contained relatively large numbers of typically tolerant forms but not a single individual of a clean-water form. Clean-water forms were expected at stations 1, 4, 8, and 10, inasmuch as they are situated outside the area polluted by

the Twin Cities. That no clean-water forms were taken from the Mississippi River below the Twin Cities above station No. 9 indicates that somewhere between station No. 7 (at Hastings, about 39 miles below St. Paul) and station No. 9 (at Red Wing, about 50 miles below St. Paul) the Mississippi River is recovering from its grossly polluted condition. The bottom fauna at station No. 11 (at the lower end of Lake Pepin) suggests a still greater improvement in the Mississippi River, while that at station No. 14 (situated at Winona about 110 miles below St. Paul) indicates that the conditions in the river here are probably as good as they are at station No. 1 (situated above the Twin Cities). The few data shown on Table 6 support the above conclusions.

PLANKTON

RELATIONSHIP OF PLANKTON ORGANISMS AND POLLUTION

A quantitative study of the plankton—the ultimate source of the food of probably all fishes—gives some information as to the abundance of the food supply. Plankton studies, however, may do more than that. Some plankton organisms are suspected of being tolerant forms—that is, they seem to thrive best in a situation where large quantities of organic matter are in a state of decomposition. Therefore, the presence of such an organism in large numbers in a plankton sample may be taken as a sign of pollution. Plankton organisms known or suspected to be tolerant are *Nitzschia amphioxys*, *Synedra ulna*, *Pleurosigma acuminatum* and *attenuatum*, among the Diatomaceæ; *Spirulina oscillarioides* and *jenneri* and five species of Oscillatoria, among the Cyanophyceæ; and *Closterium acerosum*, *moniliferum*, and *parvulum* and three species of Cosmarium, among the Chlorophyceæ. Among the zoöplankton organisms, one species of Paramecium, one species of Euglena, and at least one species of Rotifer are considered tolerant. (This list of organisms is taken from Fair's list in the revised edition of "The Microscopy of Drinking Water," by Whipple, in press, 1927.)

There are three dangers that must be guarded against in drawing conclusions from plankton studies:

1. The mere presence of a tolerant organism does not necessarily indicate polluted conditions. Only when the organism occurs in comparatively large numbers may it be taken as a criterion.

2. The absence of tolerant organisms from certain waters may not be proof, necessarily, that these waters are unpolluted. This is especially true when the study, as in the present case, is continued for a limited period of time only. Every student of the plankton knows that there are two types of plankton cycles—(*a*) the total amount of the plankton in any body of water varies with the seasons of a year and may vary even with the years, (*b*) certain species may dominate the plankton population in one season and disappear entirely in another.

3. In a river, especially after a rise in the level of the water, organisms are carried downstream. This often makes it very difficult to tell whether an organism was produced where it was taken or whether it was carried there by the current.

METHODS

Plankton samples were taken by means of a plankton pump and plankton net made of No. 20 silk bolting cloth. While taking the samples, the net was suspended over a vessel of known capacity, to measure exactly the volume of water strained for

each sample. As a rule, 25 liters were strained for each sample, but in a few cases larger volumes of water were strained. The samples were concentrated in the net to from 15 to 20 cubic centimeters and then transferred to a small vial. The materials were preserved in 4 per cent formaldehyde.

As some of the plankton organisms are too small to be retained by the net, a liter of the strained water was preserved in the field in 1 per cent formaldehyde and shipped to the laboratory for centrifuging. The centrifuging was done at the University of Minnesota with a Foerst continuous-acting centrifuge loaned by the Geology and Natural History Survey of Wisconsin. The organisms that are removed by the centrifuge constitute the nannoplankton. In the discussion of the plankton, the net plankton and nannoplankton are considered together for each station.

The method used in enumerating the phytoplankton, or plant organisms, was as follows: The sample was made up to definite volume and stirred, so that the organisms were well distributed; 1 cubic centimeter of this sample was then placed in a counting cell having an area of 1,000 square millimeters and a depth of 1 millimeter, and the number of each kind of organism in 20, 30, or 40 fields, as counted under a compound microscope, was determined. The area of the field of the microscope was known. From the concentration of the sample, the number of organisms in the various fields counted, and the area of the counting cell the number of individuals per liter was calculated. In practice, it is not necessary to make this calculation for each organism separately. All that is necessary is to make one calculation for a factor. The factor is that number which, when multiplied by the number of organisms found in the different squares counted, gives the number of organisms per liter or whatever other unit may be chosen. This factor will remain the same as long as the concentration and the number of fields counted remain constant. The factor may be calculated according to the formula $\dfrac{\frac{1,000}{a}}{V} c \times V_1 = X$. Where 1,000 is the area of the counting cell, a = the total area of the fields counted in mm.^{2}; V_1 = the volume of the sample in cubic centimeters; c = the total number of organisms in the fields counted; V = the volume of water strained through the net or centrifuge; and X = the factor. It is most convenient, in the calculations of the factor, to let c = unity.

In the case of the zoöplankton, or animal organisms, all the individuals occurring in 2 cubic centimeters of the sample, well stirred, were counted directly under a binocular. From these counts, and the concentration of the sample, the number per liter was then calculated.

Inasmuch as it is quite generally accepted that no vertical stratification of plankton organisms exists in a river with a fairly rapid flow, it was not always attempted to take samples from all levels by raising the hose of the pump at a uniform rate. As a rule, in the shallow places half the sample was taken near the surface and the other half close to the bottom. However, at stations where the water reaches considerable depth (20 to 25 feet) and where the current is slack, the pump hose was raised and lowered at a uniform rate so as to get approximately the same amount of water from all levels. Whenever expedient, two samples were taken at each station—one from the channel of the river, the other from the shallower water near shore. (See Table 7.)

TABLE 7.—*Total number of plankton organisms per liter of water*

[S=shore; C=channel]

Station	Date, 1926	Number of organisms	Station	Date, 1926	Number of organisms
1	Aug. 14	79,202	8	Aug. 19	33,494
1	Sept. 7	19,061	8	Sept. 16	186,920
2	Aug. 14	59,541	9-S	Aug. 27	49,844
2	Sept. 7	57,381	9-S	Sept. 17	92,420
3	Aug. 12	30,535	9-C	Aug. 27	65,691
3	Sept. 18	25,513	9-C	Sept. 17	98,462
4	Aug. 17	670,214	10	Aug. 27	24,596
5-S	Aug. 20	121,138	11-S	Aug. 28	23,783
5-S	Sept. 15	67,318	11-S	Sept. 18	47,551
5-C	Aug. 20	281,115	11-C	Aug. 28	11,529
5-C	Sept. 15	82,344	11-C	Sept. 18	8,518
6-S	Aug. 18	140,908	12	Aug. 28	48,081
6-C	do	45,617	12	Sept. 18	9,078
6-C	Sept. 16	43,602	14-S	Aug. 31	34,865
7-S	Aug. 18	356,678	14-S	Sept. 19	17,977
7-S	Sept. 16	60,486	14-C	Aug. 31	62,756
7-C	Aug. 18	31,585	14-C	Sept. 19	26,380
7-C	Sept. 16	73,603			

RESULTS AND DISCUSSION

Table 7 gives, for two dates (August and September), the number of plankton organisms—plants (Table 3) and animals (Table 10) combined—per liter of water at each station. The figures show that the quantity of plankton varies with the different stations (from 8,518 to 670,214 per liter). The data show also that the amount of plankton at one station varies with the date of collection. For example at station 5-C, on August 20, the number of plankton organisms per liter was 281,115; on September 15 it was 82,344; again, at station No. 8 the number per liter on August 19 was 33,494, but on September 16 it increased to 186,920.

Investigations have shown that plankton abundance can not be correlated with pollution, but to satisfy the skeptical an attempt has been made here to correlate the distribution of plankton with the varying degree of pollution. The average number of plankton organisms per liter for stations 1, 4, 8, 10, and 12 (waters at which, as shown by the dissolved-oxygen determination and a study of the bottom fauna, were not polluted) were compared with the average number for stations 3, 5, 6, 7, and 9, waters which the data on dissolved oxygen and bottom fauna had shown to be polluted. The average number for the unpolluted waters of the first group of stations was found to be 133,830; that for the polluted waters of the second group of stations was 98,050, a difference of 35,780. This difference at first may seem significant, but when one considers the great difference in the number of plankton organisms at the various stations of each of the above groups (Table 7), the differences between the shore and channel counts at the same station (Table 7), and the differences in numbers at the same station for August and September (Table 7), these differences between the above averages probably lose their signifi-

cance. The differences in the number of plankton organisms in August and September can hardly be attributed to the fact that the rains had improved conditions in the river, for the plankton at station No. 1 decreased, while that at station No. 8 increased. Both of these stations are in unpolluted waters. Stations No. 5 and No. 9 are both in polluted waters, yet the plankton at No. 5 decreased, while it increased at No. 9. (Table 7.)

In the foregoing comparison station No. 4 on the Minnesota River has been grouped with the unpolluted stations; but the data on dissolved oxygen show that its waters may be slightly polluted by the two cities some 15 miles above. (See Tables 3 and 4 and location of sampling stations, p. 141.) If we omit station No. 4 from the group of unpolluted stations, the average number of organisms for that group is reduced to 50,054, or 47,996 below the average number of organisms in the grossly polluted stations. The average number per liter for the presumably slightly polluted waters (stations 2, 11, and 14) is 35,028, or 63,022 less than for the grossly polluted waters. The variations in the abundance of the plankton may very well be explained on a basis of seasonal variations, as the samples were taken on different days and in different months. (It is a common experience that two samples of plankton taken at one place on two consecutive days may show a great difference in the number of organisms.)

The seasonal variation is well illustrated in my samples by Melosira. This plankton form was present in very small numbers at station No. 8 in August (Table 8), while nearly a month later, in September, it was very abundant (176,960 filaments per liter). I therefore believe that the data of Table 7 warrant the conclusion that no correlation exists between the total number of plankton individuals and the degree of pollution in the upper Mississippi River system, and, therefore, the abundance of plankton can not be employed as a criterion of the degree of pollution in the river.

Table 8 shows, for each genus of phytoplankton, the number per liter of water taken on the various dates at each station. It may be seen that this table includes four of the genera of algæ (Nitzschia, Synedra, Pleurosigma, and Closterium) listed by Fair as including species that are known to be tolerant (p. 152). However, most of my species of these forms are not those listed by Fair as tolerant. The exceptions are *Closterium acerosum* and *Synedra ulna*. My data (Table 8) show that the former species occurred in very small numbers at stations 2, 7, 9, and 11 (waters at stations 2 and 11 are not grossly polluted), while the latter occurred in small numbers at station No. 14 only, the waters at which, as I have already shown, were at most only slightly polluted. Obviously, *C. acerosum* and *S. ulna*, the so-called "tolerant" algæ, are, in the present survey, valueless as criteria of conditions of pollution. The Synedra found at all the other stations were identified as *S. delicatissima*, a form whose degree of tolerance has not been established.

TABLE 8.—*Total number of phytoplankton organisms per liter of water*

[S=shore; C=channel]

Phytoplankton	Sta. 1, Aug. 14	Sta. 1, Sept. 7	Sta. 2, Aug. 14	Sta. 2, Sept. 7	Sta. 3, Aug. 12	Sta. 3, Sept. 8	Sta. 4, Aug. 17	Sta. 5–S, Aug. 20	Sta. 5–S, Sept. 15	Sta. 5–C, Aug. 20	Sta. 5–C, Sept. 15
Melosira	62	1,640	1,810	300	22	209	20,780	1,870	10,950	3,680	6,300
Synedra	2,712	1,620	330	6,400	9,710	1,611	617,600	93,900	10,185	248,060	11,680
Stephanodiscus				800		11		0	9,080	3,200	8,260
Pleurosigma							1,600		22,760		11,380
Scenedesmus	8,800	4,860	10,400	10,400			24,100	6,490	2,445	11,200	11,200
Chlorella (colony)	2,400		830		4,000			1,600	2,400		
Fragilaria	800	60	30	1,600		33			180		240
Pediastrum	80		90	2,520		44	2,000	90	800		1,720
Navicula	800	800		4,860	800	2,400			800		
Pandorina					2,400		300	4,800		4,800	
Selenestrum				800			700	800			
Clococopsa				1,600							
Small diatoms	19,450	5,720	15,320	17,600		22			1,600		8,060
Nitzschia	43,200	3,200	24,000	120		20,800		180			
Chlorella (single)				3,200	13,600			8,000	800	6,400	12,800
Oocystis									1,800		
Crucigenia			1,600						800		
Amphora	862		1,720	5,660		11			800		0
Synura								800	45		3,260
Ceratium		40	30			33	1,000	800	180		3,320
Anabæna			2,520				300	1,600	135		240
Lyngbya	31		800	60				90		3,620	120
Eudorina		40									
Asterionella						11					
Closterium				800							
Actinastrum							200		135		180
Diatoma		60	60								
Cocconema		800									
Tetraspora											1,600
Microcystis		100		360		187	1,200		360		480
Aphanocapsa		80		180		77			90		
Cœlosphærium				60		33			810		960
Aphanizomenon											420
Gomphosphæria											60
Staurostrum											60
Dictyosphærium		20					200				
Clathrocystis		20		60							
Sphærocystis									90		

Phytoplankton	Sta. 6–S, Aug. 18	Sta. 6–C, Aug. 18	Sta. 6–C, Sept. 16	Sta. 7–S, Aug. 18	Sta. 7–S, Sept. 16	Sta. 7–C, Aug. 18	Sta. 7–C, Sept. 16	Sta. 8, Aug. 19	Sta. 8, Sept. 16	Sta. 9–S, Aug. 27	Sta. 9–S, Sept. 17	Sta. 9–C, Aug. 27
Melosira	11,100	0	7,230	12,720	11,800	1,920	9,080		176,960	4,000	70,220	5,430
Synedra	46,200	20,990	4,090	281,680	11,440	26,520	10,400		800	22,360	1,100	27,300
Stephanodiscus			6,500	1,660	11,960		9,000		1,720		4,040	
Pleurosigma			16,045		13,720		18,580				3,260	
Scenedesmus		8,000	3,200	35,520	1,600	120	11,320		800	12,240	3,230	15,380
Chlorella (colony)			800	3,200		60	60	3,200		4,800		10,460
Fragilaria		8,000			300		120				150	
Pediastrum				320	60	120	860			360		150
Navicula	12,300				1,720				2,400			
Pandorina					2,400		60			60		
Selenestrum				3,240	800							
Cloeocopsa				1,600	60		800			60		800
Small diatoms	12,000			160		360	240	1,600				
Nitzschia	600	8,180	800	6,400			6,400			1,720		1,600
Chlorella (single)	27,000		1,600	4,800	2,400		3,200	9,600	2,400	2,400	8,000	
Synura			800		120			1,600			1,600	30
Ceratium			1,630		360		180			860	150	30
Anabæna	3,000			160	66		60	45	800	180		90
Kirchneriella							800		800			
Lyngbya	25,200	360	45	3,400		840					30	1,660
Eudorina							60	1,600			120	60
Epithemia	3,000											
Asterionella				1,040	60	1,440	60			300	360	360
Closterium				40								
Actinastrum				200	240		980					630
Diatoma			800									
Microcystis				120	120		660		240	240	90	420
Aphanocapsa				80	60			1,350		180		90
Cœlosphærium			45	80	60		420	450				150
Aphanizomenon								13,950		60		
Dictyosphærium							120				30	
Clathrocystis												30
Campylodiscus								90				

TABLE 8.—*Total number of phytoplankton organisms per liter of water*—Continued

[S=shore; C=channel]

Phytoplankton	Sta. 9–C, Sept. 17	Sta. 10, Aug. 27	Sta. 11–S, Aug. 28	Sta. 11–S, Sept. 18	Sta. 11–C, Aug. 18	Sta. 11–C, Sept. 18	Sta. 12, Aug. 28	Sta. 12, Sept. 18	Sta. 14–S, Aug. 31	Sta. 14–S, Sept. 19	Sta. 14–C, Aug. 31	Sta. 14–C, Sept. 19
Melosira	83,500	90	4,790	4,100	60	460	28,840	4,010	14,760	1,200	17,470	3,380
Synedra	4,270	90	3,000	1,600	800	400	920		1,800	1,600	3,300	4,800
Stephanodiscus	3,090			270	550	1,320	3,710	1,000	3,600	890	2,380	1,660
Pleurosigma	800							890	900	1,600		
Scenedesmus	1,630	1,645	780	1,600			3,260	530	990	45	4,400	
Chlorella (colony)	800		4,200						900			
Fragilaria	30		360		60		1,500	30	270	90	720	
Pediastrum	30	90	600				60	30	180		180	
Navicula		9,600	690	1,600			4,000	1,000	900		6,600	
Pandorina	800						90					
Selenestrum	800											
Small diatoms	800	8,935		3,200	1,600	1,200	90	150				9,720
Nitzschia	1,600	1,645	1,800						2,700		1,100	
Chlorella (single)		1,600		28,800		3,600	3,200			12,000	16,000	
Amphora				2,400		400	1,630	500				
Synura				800		400	30					1,600
Ceratium	90		1,710	1,070	6,340	360	60		4,500	270	5,510	240
Anabæna	90		1,800					30			180	
Lyngbya	90										1,100	
Eudorina			1,080				120					
Asterionella	510			1,520	1,100	240	30	60	270	180	270	120
Stauroneis		900										4,800
Closterium	30		360	90								
Actinastrum	30						90		270			
Microcystis	210		2,340		570	120	210	360	2,520		1,800	60
Aphanocapsa	150				210		60	30			90	
Cœlosphærium	480		90	180	60		60	300	90	45	180	
Aphanizomenon											900	
Staurastrum			90	270	30		90			45	180	
Dictyosphærium					90		30					
Clathrocystis	30							150	270		360	

In this survey, *Pleurosigma spencerii*, although not known to be tolerant, is consistently much more abundant in the polluted section of the river than in the unpolluted sections and in the tributaries. It is possible, therefore, that the distribution of *P. spencerii* is correlated with the degree of pollution and that this species is a tolerant form.

To determine more definitely whether the character of the phytoplankton changes with the degree of pollution in the river, I compared the nine most abundant phytoplanktonic forms (see Table 8) found at each of three groups of stations, each group representing a different degree of pollution. Group I comprises stations 1, 8, 10, and 12 and represents unpolluted waters; Group II includes stations 2, 11, and 14 and represents presumably slightly polluted waters; and Group III consists of stations 3, 5, 6, 7, and 9 and represents grossly polluted waters. The comparative data are shown in Table 9. In this table the genera are listed according to their abundance in Group I, in a descending order. In each of the last three columns the numeral indicates the order of abundance.

Table 9 shows that seven of the genera that are among the nine most abundant in Group I are also included in the nine that are most abundant in Group III. Six of these seven genera are also among the nine listed for Group II, while Groups I and II have eight of the nine most abundant genera in common. It may be seen that *Pleurosigma spencerii* and Lyngbya sp.? are listed under Group III but nowhere else. If, in the present survey, these species are considered tolerant forms, they corroborate the conclusion based on a study of the bottom fauna, "that somewhere between station No. 7, at Hastings, * * * and station No. 9, at Red Wing, * * * the Mississippi River is recovering from its grossly polluted condition"

(p. 152); for it may be noted in Table 8 that the number of *Pleurosigma spencerii* and of Lyngbya sp.? is greatly reduced between stations 7 and 9. Table 9 shows that, to a large extent, at least, the genera that are most abundant in the unpolluted waters are also most abundant in the polluted waters.

TABLE 9.—*Nine most abundant genera for each group of stations*

Genus	Rank of genera in Group I (stations 1, 8, 10, and 12)	Rank of genera in Group II (stations 2, 11, and 14)	Rank of genera in Group III (stations 3, 5, 6, 7, and 9)	Genus	Rank of genera in Group I (stations 1, 8, 10, and 12)	Rank of genera in Group II (stations 2, 11, and 14)	Rank of genera in Group III (stations 3, 5, 6, 7, and 9)
Melosira	1	2	2	Synedra	7	5	1
Nitzschia	2	4	7	Chlorella (colony)	8	----------	9
Scenedesmus	3	3	3	Amphora	9	9	----------
Navicula	4	7	----------	Ceratium	----------	6	----------
Chlorella (single)	5	1	4	Pleurosigma	----------	----------	5
Stephanodiscus	6	8	6	Lyngbya	----------	----------	8

To recapitulate, a study of the phytoplankton of Table 8 indicates (1) that those species of plants listed by Fair as tolerant forms, and taken by me, are valueless in the present survey as criteria of conditions of pollution, and (2) that none of the other well-represented species of plants taken by me (except, possibly, *Pleurosigma spencerii* and Lyngbya) show a distinct preference for polluted waters and may be employed as criteria of the presence of pollution. Table 9 showed that, in so far as my material is concerned, the character of the phytoplankton changes little with the degree of pollution in the river, and that the plankton organisms that are most abundant in the unpolluted waters are, in general, also most abundant in the grossly polluted waters.

Table 10 shows for each date of collection the abundance per liter of water for each genus of zoöplankton taken at each field station. It may be seen that the genus Rotifer, listed by Fair as including tolerant species, occurred in my samples. Rotifer sp? occurred regularly in samples from the polluted waters and was decidedly more abundant there than in the unpolluted waters. The average number per liter for the polluted stations (Group III, Table 9) is 70.4; that for the unpolluted stations (Group I, Table 9) is 2.5. The rotifer, therefore, seems to be a tolerant form. Table 10 shows also that Nauplii are about four times as abundant in the grossly polluted waters (average per liter, 9.5) as in the unpolluted waters (average, 2.3 per liter), but that they are twice as abundant in the slightly polluted waters (17 per liter) as in the grossly polluted waters. A nauplius, therefore, can not be employed as a criterion of polluted waters. For Cyclops the average numbers of individuals per liter are 0.3 for unpolluted, 6.8 for slightly polluted, and 11.5 for grossly polluted waters. The average numbers per liter for Anuraea are 0.2 for unpolluted, 1.36 for slightly polluted, and 6.8 for grossly polluted waters. It is believed that the numbers given here for the most abundant forms (the genus Rotifer excepted), are too small to enable one to ascertain the degree of tolerance of the various species of zoöplankton. It is to be noted from Table 10 that the tolerant Rotifer is very abundant at stations 5, 6, and 7, on the Mississippi River, and declines suddenly at station No. 9. This, as in the case of bottom fauna (p. 151) and the phytoplankton (p. 157), suggests a change in the condition of the river between Hastings and Red Wing.

TABLE 10.—*Number of zoöplanktonic organisms per liter of water*

[S=shore; C=channel]

Zoöplankton	Sta. 1, Aug. 14	Sta. 1 Sept. 7	Sta. 2, Aug. 14	Sta. 2, Sept. 7	Sta. 3, Aug. 12	Sta. 3, Sept. 8	Sta. 4, Aug. 17	Sta. 5–S, Aug. 20	Sta. 5–S, Sept. 15	Sta. 5–C, Aug. 20	Sta. 5–C, Sept. 15
Nauplii	0.8	0.4		0.8		0.4	91	16	5.4		0.8
Cyclops	.8	.2	.6			.3	18	4	1.2		
Moina						30					
Bosmina								4			
Chydorus						.1					
Ceriodaphnia	2										
Noteus		.2				.6	23	8	14		
Anuraea						.4	81	8	15	55	.8
Rotifer	.8	.2			3		1.2	78	36	100	2.4
Polyarthra							90	4	1.2		
Triarthra							1.2	.4			
Distyla				.4					1.2		
Asplanchina							1.2				

Zoöplankton	Sta. 6–S, Aug. 18	Sta. 6–C, Aug. 18	Sta. 6–C, Sept. 16	Sta. 7–S, Aug. 18	Sta. 7–S, Sept. 16	Sta. 7–C, Aug. 18	Sta. 7–C, Sept. 16	Sta. 8, Aug. 19	Sta. 8, Sept. 16	Sta. 9–S, Aug. 27	Sta. 9, S, Sept. 17	Sta. 9–C, Aug. 27
Nauplii	36	3	0.2	22	13	10	12	8	2.4	9	17	8
Cyclops	60	1.2		40	.8	11				5.2	.8	2.8
Dioptomus								.6				
Bosmina				1.6							.4	
Ceriodaphnia				2						.4		1.4
Noteus				2	6		12	.6		1.8	6.4	3.2
Anuraea			.4	.8	5		11			4.4	5.2	3.2
Rotifer	408	83	16	183	33	184	46			.8	9	
Polyarthra	4			3		.8				.8		
Triarthra			.2	2.4	2.4		2.4				.8	
Distyla				1.6								2.4
Asplanchina											.4	

Zoöplankton	Sta. 9–C, Sept. 17	Sta. 10, Aug. 27	Sta. 11–S, Aug. 28	Sta. 11–S, Sept. 18	Sta. 11–C, Aug. 28	Sta. 11, C, Sept. 18	Sta. 12, Aug. 28	Sta. 12, Sept. 18	Sta. 14–S, Aug. 31	Sta. 14–S, Sept. 19	Sta. 14–C, Aug. 31	Sta. 14–C, Sept 19
Ostracoda			4.8	1.8								
Nauplii	11.2	0.4	32.4	30	39	16	0.4	4	25	7.2	19	1.2
Cyclops	.4		24	13	9	4.8	.4	.4	4	2.4	7.7	2.4
Diaptomus				.6	1.6	.8			3	1.2	1.2	
Simocephalus				2.4								
Bosmina			4.8		.4				1		.6	
Daphnia					.8				.6		4.8	
Chydorus			20	.6				1.6		.6		.6
Ceriodaphnia	.8				.4				1.2			
Noteus	5.6		1.2		.4		.4					
Anuraea	7.2	.4	2.4		7.2	1.2		1.2	1		1.8	
Rotifer	14.8				.4			.8				
Monostyla				1.4								
Polyarthra	1.6		1.2	.6							1.2	
Triarthra	.4		2.2				.4					
Distyla				.6								
Asplanchina				.6								

In an attempt to determine whether the character of the zoöplankton changes with the varying degrees of pollution, the same procedure employed for the phytoplankton (p. 157) was followed here. Table 11 lists the five most abundant zoöplanktonts for each of the three groups of stations selected (the groups of stations are described on p. 157). From this table it may be seen that four of the five planktonts that are most abundant in the grossly polluted waters occur also among the five that are most abundant in the unpolluted waters. My inadequate material shows that the zoöplankton in the unpolluted sections of the river and tributaries is not markedly different in quality from the zoöplankton of the polluted sections of the river, and that, with the exception of Rotifer, the species taken by me can not be employed as indices of the degree of pollution in the Mississippi River.

TABLE 11.—*The five most abundant zoöplanktons for each group of stations*

Genus	Rank in Group I (stations 1, 8, 10, and 12)	Rank in Group II (stations 2, 11, and 14)	Rank in Group III (stations 3, 5, 6, 7, and 9)	Genus	Rank in Group I (stations 1, 8, 10, and 12)	Rank in Group II (stations 2, 11, and 14)	Rank in Group III (stations 3, 5, 6, 7, and 9)
Cyclops	3	2	2	Ceriodaphnia	2		
Rotifer	3		1	Noteus	5		
Nauplii	1	1	3	Bosmina		5	
Anuræa	4	4	4	Chydorus	4		
Polyarthra			5				

FISHES

SUMMARY OF SEINING OPERATIONS AND RESULTS

As stated in the introductory part of this report, the people of Minnesota and Wisconsin claim that the number of fish has decreased in their section of the Mississippi River, but no specific data are available to support this contention. Unfortunately, the writer was not able to seine at all the stations, but the stations where seining was done are so distributed that it is possible to determine whether there is any correlation between the number of fish and the degree of pollution in the river. Seine hauls were made at or near stations 1, 2, 4, 5, 6, 7, 9, and 10. The equipment used consisted of a flat-bottomed gasoline launch, a rowboat, and a seine 150 by 6 feet of ¼-inch mesh. The fish were preserved in 4 per cent formaldehyde and sent to Dr. John Van Oosten, of the United States Bureau of Fisheries, for study. Doctor Van Oosten's determinations were checked by Carl L. Hubbs, of the University of Michigan zoological museum.

Stations 1 and 2.—The seining at stations 1 and 2 was done on August 21. The first haul at station No. 1 yielded the 362 fish shown in Table 12, in addition to one 18-inch common sucker and 75 crayfish. The second haul contained at least 1,500 small wall-eyed pike, numerous minnows, a few bullheads, a few suckers, and a number of crayfish. The fish retained are listed in Table 12.

The first haul at station No. 2 consisted of the 547 fish, shown in Table 12, one 10-inch pickerel, and one 6-inch smallmouth black bass. The second haul consisted of a school of black bullheads, many wall-eyed pike, and several hundred shiners. Part of this haul is listed in Table 12. The hauls at station No. 2 were made in the left branch of the channel, which is less polluted locally than is the right branch. Many fish were seen along the left bank (east side) of the river at station No. 2. A few were seen also along the side of the island in the right branch of the channel.

Station 4.—On August 17 three seine hauls were made in the Minnesota River at station No. 4. The partial results of these hauls are shown in Table 12. In one of the hauls 350 gizzard shad were taken but were thrown back. They do not appear in the table. A number of shiners and sunfish likewise were thrown back into the river. Crayfish seemed to be plentiful at this station.

Station 5.—On August 20 three seine hauls were made at station No. 5. Only one 1.5-inch stickleback was taken.

TABLE 12.—*Upper Mississippi River biological survey, 1926. Number of each species of fish retained from each haul at the various field stations. Names of species are taken from Hubbs' Check List of Great Lakes Fishes*

Species	Station 1, Camden Bridge, Aug. 21		Station 2, Plymouth Bridge, Aug. 21		Station 4, Minnesota River, Aug. 17			Station 8, St. Croix River, Aug. 19			Total
	Haul 1	Haul 2	Haul 1	Haul 2	Haul 1, above Cedar Avenue bridge	Haul 2, below Cedar Avenue bridge	Haul 3, Fort Snelling	Haul 1, junction of the two rivers	Haul 2, above bridge	Haul 3, a mile below junction	
Dorosoma cepedianum (gizzard shad)					12	2					14
Catostomus commersonnii (common sucker)	49	2	125			2					178
Moxostoma anisurum (white-nosed sucker)			1								1
Moxostoma lesueurii (short-nosed red horse)	19		5								24
Pimephales promelas p. (black-head minnow)					5	3	8				16
Hyborhynchus notatus (blunt-nosed minnow)	12		28	1			2				43
Semotilus atromaculatus a. (horned dace)	14		14								28
Notemigonus crysoleucas (golden shiner)								2		1	3
Ceratichthys vigilax (bullhead minnow)					5	1	32				38
Notropis anogenus					1						1
N. atrocaudalis					2		3		1		6
N. heterodon richardsoni								2		2	4
N. deliciosus (straw-colored minnow)					80	1	8			10	99
N. gilberti					1		9				10
N. hudsonius selene (spot-tailed minnow)			1	1			7	79	10	33	131
N. whipplii whipplii (steel-colored minnow)					29		12	5			46
N. cornutas frontalis (common shiner)	113	1	311	27							452
N. blennius					3		8		1	6	18
N. antherinoides (shiner)				1	140	2	5				148
N. rubrifrons (rosy-faced minnow)										2	2
N. buchanani							31				31
N. boops							1				1
Rhinichtys atronasus (black-nosed dace)			1								1
Nocomis biguttatus (river chub)	11		37								48
Ameiurus melas (black bullhead)	5		10								15
Schilbeodes gyrinus (tadpole cat)			1								1
Fundulus diaphanus menona (menon top minnow)			4		1	2	9				16
Percopsis osmisco maycus (trout perch)	71	2	2								75
Pomoxis annularis (white crappie)					4	1	8				13
Pomoxis sparoides (black crappie)	24		1			1	1	3	35		65
Ambloplites rupestris (rock bass)	12							3			15
Apomotis cyanellus (green sunfish)	2		1			1					4
Lepomis humilis (orange-spotted sunfish)					2	3					5
Helioperca incisor (bluegill)						9	3				12
Eupomotis gibbosus (pumpkinseed)	2					2					4
Micropterus dolomieu (small-mouth black bass)			2								2
Aplites salmoides (large-mouth black bass)								3	2		5
Stizostedion vitreum (wall-eyed pike)	2		2								4
Perca flavescens (yellow perch)						1		105	46	60	212
Percina caprodes zebra (log perch)									10	94	104
Imostoma shumardi										2	2
Boleosoma nigrum nigrum (Johnny darter)	26		1		16	3	83		1		130
Lepibema chrysops (white bass)								1	2		3
Percina X Cottogaster (hybrid)										1	1
Total	362	5	547	30	301	34	230	203	108	211	2,031

Stations 6 and 7.—On August 18 two seine hauls were made at station No. 6, on the Mississippi River. No fish were caught in these hauls. On the same day another haul was made about 7 miles below station No. 6, but here, again, no fish were taken. At this latter place one haul was made in a slough still connected with the Mississippi River. Here one short-nosed gar was taken. This fish was very sluggish. A haul made at station No. 7 on the evening of August 18 likewise took no fish.

On August 19 four hauls were made on the Mississippi River between Hastings and St. Paul. Three of these were made between stations 6 and 7. One was made just above South St. Paul (that is, between stations 5 and 6). Not a single fish was taken in these hauls.

Station 8.—On August 19 four seine hauls were made at station No. 8. One haul was made on the St. Croix side at the junction of the St. Croix and the Mississippi Rivers. This haul was not very successful because the net rolled; yet it netted the 203 fish shown in Table 12, 1 adult red horse, and 1 adult yellow perch. The last two were thrown back and were not recorded in the table. The second haul, made on the Mississippi River side, netted one turtle. The waters of the two rivers have not yet mixed here. A third haul was made in the St. Croix River, about ⅓ mile above its mouth. Here aquatic plants were very abundant along the shore and interfered seriously with making the haul. The bulk of the fish taken here consisted of yellow perch and black crappies. At least 150 of each were thrown back and were not recorded in the table. The fourth haul was made on the Wisconsin side of the Mississippi River, about 1 mile below the mouth of the St. Croix River. This haul yielded the 211 fish shown in Table 12, besides 1 large red horse, 1 large pumpkin seed, and 5 four-inch yellow perch. It is doubtful if the waters of the two rivers are mixed to any great extent even here. Time did not permit the making of another haul on the Minnesota side of the river.

Stations 9 and 10.—On August 28 two seine hauls were made in the Cannon River, a short distance below station 10, and one in the Mississippi River, about 1½ miles above Red Wing (station No. 9). Because of the high water, weeds, and fallen logs, these hauls were not successful. No fish were taken in the Cannon River, and only one common shiner was taken in the Mississippi River. The waters of the Mississippi River were pushing up into the Cannon River. This made the latter so turbid that if any fish were present they could not be seen. When the writer revisited this river about 2 miles farther up its course, the water was clear and a number of small fish were seen.

The above data show (1) that fish are abundant at stations 1 and 2 on the Mississippi River, at stations 4 and 8 on the Minnesota and St. Croix Rivers, respectively, and in the Mississippi River (Wisconsin side) about 1 mile below the mouth of the St. Croix River; (2) that fish are very scarce, if present at all, in the Mississippi River at and between stations 5, 6, and 7, and in the waters of the Mississippi proper (that is, in the Mississippi waters that were not yet mixed with those of the tributaries), at or near stations 8 and 9. Commercial fishing above Red Wing did not commence until the latter part of August, and then only around the mouths of tributaries. Below St. Paul carp fishing did not begin until about the middle of September, one month after the beginning of the heavy rains.

DISCUSSION—FISH AND POLLUTION

It was shown on page 144 that during August (all my seining was done from August 17 to 28) "the dissolved-oxygen content is decidedly less in that section of the Mississippi River which extends from station No. 2, at the beginning of the metropolitan area, to station No. 9, at the head of Lake Pepin (a distance of approximately 64 miles) than it is above or below this section or in the tributary waters," and "at station No. 9 conditions with respect to dissolved oxygen are much better than they are at stations 3, 5, 6, and 7, but are not nearly as good as they are at stations 1, 2, 11, and 14." Again, it was concluded from a study of the bottom fauna (p. 151) and of the phytoplankton and zoöplankton (pp. 157 and 159,

respectively) that somewhere between station No. 7 (at Hastings, about 39 miles below St. Paul) and station No. 9 (at Red Wing, about 50 miles below St. Paul) the Mississippi River is recovering from its grossly polluted condition.

It is precisely in that section of the Mississippi River (from stations 1 to 9) where the oxygen content was decidedly low that fish were extremely scarce or absent altogether (see p. 162). At the stations on the Mississippi River (Nos. 1 and 2), where oxygen was plentiful, fish also were abundant. Fish were numerous also in the relatively unpolluted tributaries—the Minnesota and the St. Croix Rivers. The close correlation between the abundance of fish and the presence of oxygen is well demonstrated by the results of the seining at a near station (No. 8, p. 162, fig. 1). A seine haul made in the polluted waters of the Mississippi River proper took one turtle only, whereas hauls made in the relatively unpolluted waters of the St. Croix or in the partially polluted waters of the Mississippi, below the mouth of the St. Croix, netted many fish. It is unfortunate that attempts to seine succeessfully at station No. 9 met with failure, for it would be of great interest to know whether the improvement in the condition of the river here was sufficient to permit fish to live. The fact that one shiner was taken suggests that fish were present at this station in August.

Thompson (1925), who has made an extensive study of the oxygen requirements of fishes in the Illinois River, writes: "It seems quite certain that dissolved-oxygen concentration between zero and two parts per million will kill all kinds of fish. Carp and buffalo have been found living in water showing as low as 2.5 parts per million. As a rule, a variety of fishes was found only when there were four or more parts per million, and the greatest variety of fishes was taken when there were nine parts per million."

If the findings of this author are applicable to the fish of the Upper Mississippi River, an examination of the data on oxygen (Tables 3 and 4) shows (1) that no fish whatsoever can live continuously in the waters at stations 3, 5, 6, and 7 during August and the first week of September, or at station 9 during the first three weeks of August; (2) that a limited variety of fishes (the more tolerant species) can live at station No. 9 (Red Wing) after the third week in August; (3) that virtually any fish can live, in so far as oxygen is concerned, at the stations not mentioned above during August and September; and (4) at all stations, polluted and unpolluted, with the possible exception of Nos. 7 and 9, during the high-water stage after the heavy rains in September.

These conclusions agree very well with the statements made on page 162, which suggest that the commercial fish make their first appearance in the fall, during the latter part of August, in the vicinity of Red Wing (station No. 9), and about the middle of September farther up the river near St. Paul.

The correlation between the abundance of the species and of the individuals of species, and the characteristics of each station at which seine hauls were made, is most striking. Table 13 shows the relationship between the amount of dissolved oxygen, the character of the bottom fauna, the abundance of tolerant planktonts, the estimated average number of fish per seine haul, and the approximate number of species of fish. From this table it may be seen that the stations at which the dissolved-oxygen content is high, the dominant bottom animals are clean-water

forms, or the tolerant bottom forms are relatively scarce, and the presumably tolerant planktonts (*Pleurosigma spencerii*, Lyngbya sp.? and Rotifer sp.?) are absent or sparse, have many fish and many species of fish; and, vice versa, those stations at which the oxygen concentration is low, the dominant bottom forms are tolerant, clean-water forms are absent, and the tolerant planktons are relatively very abundant, have practically no fish. Table 13 shows, beyond any doubt whatsoever, that the absence or scarcity of fish in August in that section of the Mississippi River that extends from the beginning of the metropolitan area of the Twin Cities to Prescott, Wis. (a distance of approximately 39 miles), is due to the pollution from the former cities.

TABLE 13.—*Relationship between the amount of dissolved oxygen, the character of the bottom fauna, and the abundance of the tolerant planktonts Pleurosigma spencerii, Lyngbya sp. ?, and Rotifer, and the estimated number of fish per seine haul and the approximate number of species at stations 1 to 8, No. 3 excepted*

Station	1	2	4	5	6	7	8
Parts per million dissolved oxygen, average for August	6.59	6.08	5.70	0.87	0.51	0.39	7.10
Character of bottom fauna	Clean-water forms dominate; tubificids few.	Few midge larvæ only.	Few tubificids only.	Tolerant forms abundant; no clean-water forms.	As in 5.	As in 5.	As in 1.
Abundance of *Pleurosigma spencerii*, average number per liter	0	------------	1,600	17,070	16,045	16,150	0
Abundance of Lyngbya sp. ?, average number per liter	31	430	0	1,276	8,535	2,120	0
Abundance of Rotifer sp. ?, average number per liter	.5	0	1.2	54.1	169	111.5	0
Average number of fish per seine haul	[1] 1,000?	750?	330?	1/3	0	0	330?
Number of fish species per seine haul	[2] 14?	19?	24?	1	0	0	17?

[1] Questionable values were estimated.
[2] Questionable values indicated that the species thrown back and not identified are not included.

It may be emphasized here that, so far as our data show, the distribution of fish in the polluted upper Mississippi River is primarily—probably entirely—limited by the amount of oxygen present in the waters. If toxic chemical ingredients are present in sufficient quantities to act as poisons, they may be the primary controlling factors; but we have no direct information concerning this subject. The abundance of plankton and tolerant bottom forms in the grossly polluted waters suggests that chemical poisons, if present, are not sufficiently concentrated to destroy life outright. The paucity in the variety of bottom foods in the polluted areas may be a minor factor in the distribution of fish that subsist mainly on bottom fauna; but plankton as food is not a factor in the scarcity of fish, for we have shown (p. 154) that the planktonts are abundant, in individuals and in variety of species, in both polluted and unpolluted waters.

In conclusion, it should be stated that the data presented in this paper suggest that the pollution of the upper Mississippi River is severe only (in so far as fish are concerned) during the periods of low water—that is, sometime during midwinter (January and February) and during midsummer (July and August). (See p. 142.) From the point of view of conservation this is highly significant; it should be investigated by continuous observations throughout a period of at least one year.

SUMMARY OF RESULTS

1. This biological survey of the upper Mississippi River system was undertaken by the Bureau of Fisheries at the request of the States of Minnesota and Wisconsin. The field work was done during the period August 12 to September 27, inclusive, and covered approximately the same territory now under investigation by the United States Public Health Service—viz, the Mississippi River from above Minneapolis (Camden Bridge) to Winona, Minn., a distance, by water, of approximately 120 miles, and the following tributaries: The Minnesota, St. Croix, Cannon, and Chippewa Rivers.

2. During August and the first week of September, 1926, the dissolved-oxygen content was decidedly less in that section of the Mississippi River that extends from station No. 2, at the beginning of the metropolitan area of the Twin Cities, to station No. 9, at Red Wing, at the head of Lake Pepin (a distance of approximately 64 miles), than it was above or below this section or in the tributary waters. It was concluded that this decrease or depletion of dissolved oxygen was due primarily to the pollution of the river by the cities of Minneapolis and St. Paul.

3. All the bottom samples taken from the Mississippi River between station No. 1, above the metropolitan area, and station No. 9, at Red Wing, at the head of Lake Pepin (except in one of the samples taken between stations 2 and 3 in the metropolitan area, which took no aninals at all), took relatively large numbers of typically tolerant (pollution) forms, but not a single individual of a clean-water form. Clean-water forms first appeared in the bottom samples of the Mississippi below Minneapolis, at station No. 9, at Red Wing.

4. The major portion of the organic residue of the strained bottom samples taken from the Mississippi River between stations 1 and 9 consisted of coarse organic débris and garbage, whereas the greater part of the residue of the samples taken outside of this area and examined consisted of cleaner materials such as aquatic plants, empty mollusk shells, sand, chips of wood, etc.

5. A study of the plankton showed that only three of the species taken by me may be considered tolerant forms—that is, forms that may be employed as rough criteria of the degree of pollution. Two of the three species (*Pleurosigma spencerii* and Lyngbya sp.?) are plants (phytoplankton), while the third (Rotifer sp.?) is an animal (zoöplankton). These forms usually were found to be comparatively very abundant when taken at stations situated in the more polluted waters but relatively sparse when taken from less polluted waters. All three forms showed a marked decline in abundance at station No. 9, at Red Wing. The species of phytoplankton listed by Fair as tolerant forms and taken by me could not be employed in this survey as criteria of conditions of pollution.

6. The data on dissolved oxygen, the organic composition of the residue of strained bottom samples, the bottom fauna, and the tolerant plankton forms all show (1) that the waters of the Mississippi River were badly polluted from Minneapolis to Hastings, a distance of about 49 miles; (2) that somewhere between Hastings and Red Wing (situated about 15 miles farther downstream) the river recovered somewhat from its grossly polluted condition; (3) that at station No. 11, at the lower end of Lake Pepin, conditions with respect to pollution were much improved;

and (4) that at station No. 14, above Winona (situated about 110 miles below St. Paul) very little, if any, pollution was present, for conditions here compared favorably with those at station No. 1, situated above the polluted areas at Minneapolis.

7. Fewer species of bottom forms were taken in the more polluted waters (about 6 species) than in the less polluted or unpolluted waters (about 20 species).

8. I found that no correlation existed between the total number of plankton individuals and the degree of pollution in the upper Mississippi River system, and therefore the abundance of plankton can not be employed as a criterion of the degree of pollution.

9. My samples show that, on the whole, the character of the phytoplankton and zoöplankton changes very little with the degree of pollution in the river; the plankton organisms that are most abundant in the unpolluted waters are, in general, also most abundant in the grossly polluted waters.

10. The hydrometric data show that the discharge of the Mississippi River and of its tributaries varies considerably during the year, the rate alternating in cycles of minimum and maximum flow. The periods of low water occur sometime during midsummer (July and August) and midwinter (January and February), the periods of high water sometime during March, April, and May and during September and October.

11. The data on seine hauls show (*a*) that fish were abundant at stations 1 and 2, on the Mississippi River at the beginning of the polluted metropolitan area; at stations 4 and 8, on the Minnesota and St. Croix Rivers, respectively; and in the Mississippi River about a mile below the mouth of the St. Croix, but (*b*) very scarce, if present at all, in the section of the Mississippi River that extends from station No. 5 (just below St. Paul) to the St. Croix River, a section about 39 miles long. In 1926, commercial fishing in the Mississippi River commenced about the latter part of August in the vicinity of Red Wing and about the middle of September in the vicinity of St. Paul.

12. From a study of dissolved-oxygen concentration, it was concluded (*a*) that no species of fish could live continuously in the Mississippi River between stations 3 (in the metropolitan area) and 7 (Hastings) during August and the first week of September, or at station 9 (Red Wing) during the first three weeks in August; (*b*) that the more tolerant fish could live at station No. 9 after the third week in August; and (*c*) that virtually any fish could live, in so far as oxygen is concerned, at the stations not included in the above during August and September, and (*d*) at all stations, polluted and unpolluted (with the possible exception of 7 and 9), during the high-water stage after the heavy rains in September.

13. At stations where the dissolved-oxygen content is high, it was shown that the dominant bottom animals are clean-water forms, the tolerant bottom forms are relatively scarce, the tolerant planktons are absent or sparse, and fish are numerous and of many species; and, vice versa, at stations where the oxygen concentration is low the dominant bottom forms are tolerant, clean-water forms are absent, the tolerant planktons are relatively very abundant, and there are virtually no fish. From these facts it was concluded that the absence or scarcity of fish in the upper Mississippi River during August, 1926, was due primarily to the pollution from Minneapolis and St. Paul.

14. It was suggested that dissolved oxygen is the controlling factor in the distribution of fish in the polluted upper Mississippi River. The paucity in the variety of bottom foods in the polluted areas may be a minor factor in the distribution of fish that subsist mainly on bottom fauna. Plankton, as food, is not a factor in the distribution of the fish, for plankton was abundant, both in individuals and in species, in polluted as well as in unpolluted waters.

15. It was suggested further that the data indicate that the pollution of the upper Mississippi River is severe only (in so far as fish are concerned) during the periods of minimum discharge—that is, the periods of low water. It is highly desirable that the distribution of the fish be studied through the various periods of minimum and maximum discharge.

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QUANTITATIVE STUDY OF THE CHANGES PRODUCED BY ACCLIMATIZATION IN THE TOLERANCE OF HIGH TEMPERATURES BY FISHES AND AMPHIBIANS

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CONTENTS

INTRODUCTION

A great many observations have been made by numerous experimenters on the maximum temperatures tolerated by organisms. In 1895 Davenport and Castle listed thermal death points that had been determined for 69 species of plants and animals; and the number of species studied, especially of microorganisms, has been increased greatly since that time. Quantitative studies on acclimatization as a factor in the tolerance of high temperatures began with the observations of Flourens (1846) and Ehrenberg (1859), who reported organisms living in hot springs at temperatures of 85° and 98° C., when closely allied species in the waters of the same region ordinarily were exposed to temperatures no higher than 40° C. Schwartz (1884) and Aderhold (1888) found that Euglena collected in summer ceased activity when the temperature fell to 5° or 6° C., while those collected in winter remained active at 0° C.

The most notable work on experimental acclimation of microorganisms is that of Dallinger (1880) on flagellates. By gradually raising the temperature of his cultures, he was able, within a period of several years, to change their limits of tolerance from 23° to 70° C. Jollos (1921) has shown that protozoans acclimated to high temperatures and to certain chemicals may retain their increased tolerance for many generations in the absence of the acclimating agent.

Pioneer work on acclimatization of vertebrates was that of Davenport and Castle (1895). They tested the tolerance of toad tadpoles by raising the temperature of the surrounding water at the rate of about 25° C. in 10 minutes, and noted the

temperature at which the tadpoles went into heat rigor. They found that individuals reared at 15° C. went into rigor at 40.3°, while for those that had been kept at 25° C. for 28 days the limit of tolerance was 2.3° higher. The increased resistance was only partly lost in 17 days at 15° C. Loeb and Wasteneys (1912) tested the duration of survival at high temperatures of Fundulus that had been kept at 10° and 27° C. Individuals that had been kept at 10° C. died in four hours at 25° C., while 30 hours' exposure to 27° C. enabled the fishes to survive indefinitely at 35° C. By short exposures on successive days to temperatures that normally would have killed the fishes the tolerance limit was raised to 39° C., and the added resistance was not wholly lost in several weeks at a temperature near the freezing point.

A few suggestions have been made regarding the nature of the changes involved in acclimatization. Davenport, in 1897, suggested that increase in tolerance might be caused by a lowering of the water content of protoplasm, with consequent raising of the temperature necessary to cause coagulation. Loeb and Wasteneys (1912) compare acclimatization with the annealing of glass, while Miss Behre (1918) has presented evidence indicating that an adjustment in metabolic rate is an important factor in acclimatization. She shows that raising or lowering the temperature of Planaria alters the rate of metabolism, but that continued exposure to high or low temperature is accompanied by a gradual return to the original rate.

In spite of the large amount of work done on temperature tolerance, the methods employed have been so varied that there seems to be no satisfactory way of comparing, quantitatively, the results obtained by the various workers, and hence there is no basis for an accurate comparison of different animals. The purposes of the present study are as follows:

1. To find a method of studying, quantitatively, the changes in tolerance produced by acclimatization, which will be applicable to a wide variety of kinds of animals.

2. By the use of this method to determine, for each of several different animals, the relative amounts by which the tolerance of high temperatures can be modified, and to see whether the power of adjustment bears any definite relation to the ecology of the animals and to their taxonomic position.

3. To afford, by the work on tolerance, a point of departure for further experiments on the physiological nature of acclimatization.

This work was undertaken at the suggestion of Prof. A. S. Pearse, to whom the writer is under great obligation for advice and assistance. The writer is indebted to Dr. J. R. Roebuck and to Dr. F. G. Hall for suggestions regarding construction of apparatus, and to Dr. Willis H. Rich for reading and criticizing the manuscript. The work was supported, in part, by funds provided by the Bureau of Fisheries.

GENERAL PLAN OF THE EXPERIMENTS

MATERIAL

Five species of animals were used in these experiments—the yellow perch, *Perca flavescens* (Mitchill); the large-mouthed black bass, *Micropterus salmoides* (Lacépedè); the bluegill, *Lepomis incisor* (Mitchill); the sunfish (pumpkinseed), *Eupomotus gibbosus* (Linnaeus); and the tadpoles of the toad, *Bufo americanus* Le Conte.

Several considerations led to the choice of these animals. In the first place, it was decided that this introductory work should be done on the members of a well-defined group, within which the relation of ecology to modifiability of tolerance could be studied effectively. An attempt to compare animals belonging to different phyla involves such profound differences in structure and physiology that several members of each great group must be studied in detail in order to obtain results that are of ecological significance, so it was thought that each of the larger groups should be considered in a separate series of experiments. The present study, therefore, is limited to gill-breathing vertebrates.

The fishes named were chosen for the reasons that they are abundant and easily obtained in Lake Mendota, and that they represent a fairly wide range of habitat preferences (Pearse, 1918 and 1921; Pearse and Achtenberg, 1920), *Micropterus salmoides*, *Eupomotus gibbosus*, and *Lepomis incisor* being essentially shallow-water fishes, while *Perca flavescens* is, by preference, an inhabitant of lower levels. Toad tadpoles were studied as another type of gill-breathing vertebrate because, commonly living in small bodies of water, they would be expected to withstand rather wide and rapid fluctuations in temperature.

In most of the experiments on fishes, individuals between 1 and 2 years of age were used, those less than 1 year old being very sensitive and hard to handle, while older specimens could be used only in very small numbers because of limited space in the constant-temperature baths. The young fishes possessed the further advantage that they were not passing through the physiological changes that accompany the different phases of the annual reproductive cycle. All of the tadpoles used had easily visible hind legs. They developed rapidly during the experiments, but, unless otherwise stated, none of them had visible front legs at the times of the tests.

All of the fishes used were seined from Lake Mendota. The tadpoles were obtained in some large, shallow pools in South Madison, several collections being made in the course of the work. All specimens were brought to the laboratory as soon as possible after being collected and were kept in large aquaria and battery jars with a constant flow or frequent changes of water. No animals were used in the tests until they had been in the laboratory at least 48 hours, as it was found that in the first day or two after being brought in their resistance to heat was extremely variable.

METHOD OF MEASURING TOLERANCE

In this quantitative study it was necessary (1) to decide what should be considered as constituting tolerance and (2) to find a fairly accurate, numerical means of expressing the degrees of tolerance possessed by different individuals. After a number of preliminary experiments it was decided to express tolerance in terms of the maximum temperatures that could be survived for periods of 1 minute, 4 minutes, 15 minutes, 1 hour, 4 hours, and 24 hours. The 24-hour tests were considered the most significant and the others served as checks upon them. The maximum temperatures that could be endured for the various lengths of time are referred to as the "24-hour tolerance limit," the "4-hour tolerance limit," etc. The general method of procedure was as follows:

1. Tests were made (usually simultaneously) at two or three constant temperatures, 2° C. apart, the lowest of which was believed to be near the upper limit of tolerance of the individuals tested.

2. Observations were made 1 minute, 4 minutes, 15 minutes, 1 hour, 4 hours, and 24 hours, respectively, after the beginning of each test.

3. At every observation the condition of each individual was recorded, and the time of the last reading at which an individual was alive was recorded as its survival time.

Two reasons led to the choice of the method just described—(1) it is relatively simple and is applicable to tests on a considerable number of individuals; (2) the time periods into which the tests were divided (1 minute, 4 minutes, etc.), constitute, roughly, a geometric progression. Therefore, the degrees of tolerance represented by survival for the various lengths of time belong to different orders of magnitude, and the method affords a quantitative basis for the comparison of the tolerance of various individuals and species.

Fishes were considered dead when respiratory movements had ceased, as no case of recovery following cessation of respiration was ever observed. In tadpoles no great effort was made to distinguish between heat rigor and death. The distinction proved to be unimportant, for many observations showed that recovery from rigor never occurred except during the first hour of the test. Failure to move in response to repeated mechanical stimulation with a blunt glass rod was taken as evidence that a specimen was dead or in rigor.

In the early stages of the work it became apparent that, under the conditions employed, the tolerance limits for the members of a given species that had received a certain treatment lay within rather definite limits. For example, all normal bluegills and sunfishes survived at 34° and none at 36°. In other cases the thermal death points were less definite, but, on the average, an increase of 2° in the trial temperatures was sufficient to bring about a change from 90 per cent survival to 90 per cent death. However, the tolerance limit of the majority of the individuals was found not to be a satisfactory basis for comparisons, as the tolerance of the average individual may fall above or below that of the mode. For this reason the average tolerance limit was computed for each series, the following equation being used:

$$\frac{tP_1+(t-2)P_2+(t-4)P_3}{100}=T$$

In this equation, t is the highest temperature tolerated for the given period by any of the individuals tested; $t-2$ and $t-4$ are temperatures, respectively, 2° and 4° below t; P_1, P_2, and P_3 are the percentages of individuals for which t, $(t-2)$, and $(t-4)$ are, respectively, the maximum temperatures tolerated; and T is the average of the tolerance limits of the individuals in the series.

The manner of applying the foregoing formula may be illustrated by the case of the normal bass tested at 30°, 32°, 34°, and 36°. The percentages of individuals surviving at these temperatures were as follows:

Degrees	Per cent
30	100
32	86
34	26
36	0

Hence, $t=34°$. From these results it seems fair to assume that the 14 per cent that died at 32° would have survived at 30°; hence, $P_3=14$. Furthermore, the

26 per cent of survivals at 34° indicates that out of the 86 per cent that survived at 32°, 26 per cent would have survived at 34°. Hence, $P_1=26$ and $P_2=60$, and T equals approximately 32.3°. The advantage of this average tolerance limit over the simpler majority limit, as a basis for measuring acclimatization, is illustrated in Table 1, which shows that the majority tolerance lies distinctly below that of the average in the cases of bass and toad tadpoles, and decidedly above it in the case of the perch.

TABLE 1.—*Maximum temperatures tolerated for 24 hours by a majority and an average of normal individuals*

	Majority	Average
	° *C.*	° *C.*
Perch	30	29.6
Bass	32	32.2
Bluegill	34	34.0
Sunfish	34	34.0
Toad tadpoles	36	36.3

METHOD OF ACCLIMATIZATION

In attempting to test the relative ability of various animals to become acclimated, it was decided to make the following determinations for each species:

1. The tolerance limits of individuals that had been living at room temperature. These individuals are referred to as normals.

2. The extent to which tolerance limits were raised by exposure for varying lengths of time to a temperature of 30° C.

3. The extent to which tolerance limits were lowered by exposure for varying lengths of time to a temperature of 10° C.

The temperature in the aquaria in which the normal animals lived averaged between 22° and 23° C. The members of all the different species showed decided stimulation when transferred to 30° C., and a temperature of 10° C. was low enough to decrease activity and feeding very markedly.

The acclimatization periods used for fishes were 1 day, 4 days, and, when practicable, 16 days. In the work on toad tadpoles, periods of 1 hour, 4 hours, 1 day, 4 days, and 8 days were employed, development occurring too rapidly to permit the use of 16-day periods with the individuals available.

DETAILS OF METHODS

APPARATUS

The principal pieces of apparatus used consisted of (*a*) a cold box, which was kept at about 10° C.; (*b*) a series of seven constant-temperature baths, adjustable for any desired heat above room temperature; and (*c*) an aeration system, by which air was bubbled through the jars of water containing the fishes.

The cold box consisted of outer and inner wooden cases, inclosing an outer and an inner sheet-iron tank. The jars containing the specimens stood in water in the inner sheet-iron tank, which, in turn, was surrounded by the water filling the outer tank. Insulation was furnished by the inner and outer wooden cases, the double glass doors of which permitted good illumination. The baths for use at higher

temperatures were wooden tubs, each large enough to hold four or five of the battery jars containing the specimens. An electric heating unit was placed in the bottom, so that stratification of the water was prevented almost entirely by the convection currents; and the temperature was controlled by a mercury thermostat, which operated a relay in the heating circuit. The aeration system was not needed in the work on tadpoles but was essential for the fishes, because the limited capacity of the constant-temperature baths and the need of testing separately a large number of individuals necessitated the use of rather small jars for the specimens. Air at low pressure was supplied by a specially designed suction pump, from which a rubber tube led to each specimen jar, where a fine glass tip delivered the bubbles in a stream that was strong enough to stir the water well. At or below room temperature this system normally furnished ample aeration, the respiration of the fishes apparently being normal.

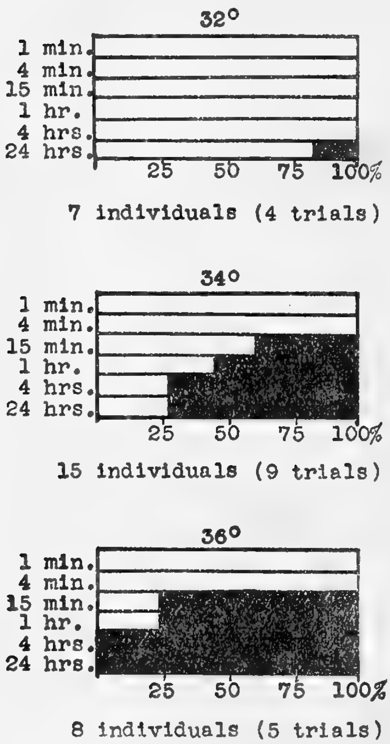

FIG. 1.—Effects of high temperatures on "normal" large-mouthed black bass. The specimens were transferred directly from room temperature to the test temperatures (32°, 34°, and 36°, respectively). The six lines in each rectangle represent successive observations on the same individuals. The lengths of the sectors in each line show the percentages of individuals that were living or dead at the time of each observation. ▭ living; ■ dead

ACCLIMATIZATION CONDITIONS

Acclimatization was carried on in battery jars, different sizes being used, according to the size and number of the specimens. Tadpoles were run in lots of 10 to 20 without artificial aeration; fishes, in lots of 1 to 4 with aeration. In all cases the jars used were large enough, so that the fishes could turn around without touching the sides of the vessel. All specimens were fed during the acclimatization periods.

TEST CONDITIONS

Lake Mendota water, drawn from the university taps, was used in all the tests, being brought to the desired temperature and then stirred vigorously to remove excess air. Ordinarily, it was probably just about saturated with oxygen at the beginning of each experiment.

The tests on the fishes were made in battery jars, about 1,800 cubic centimeters of water being used for yearling fishes and about 5 liters for the larger individuals. Tadpoles usually were tested in groups of three in specimen jars containing 250 cubic centimeters of water. Transfers were made directly from the acclimatization temperatures to the test temperatures, and there was no feeding during the 24-hour test periods.

DEGREE OF ACCURACY MAINTAINED

Acclimatization periods listed as 24 hours include a few as low as 22 and a few as high as 27 hours. The ordinary variation in the so-called 4-day periods was between 92 and 100 hours, while periods of from 15 to 17 days were included in the 16-day

group. During the test periods, especially during the early hours, observations usually were made exactly on schedule times, or within a very few minutes of them.

In acclimatization at 30° specimens were discarded if the temperature was found to have risen above 31°. The work of Loeb and Wasteneys (1912) had shown that exposure for a short time to a high temperature produced lasting results, and, as will be seen later, experiments in this series bore out their conculsion; so it was felt that an exposure to a temperature of 31° for even a short time was enough

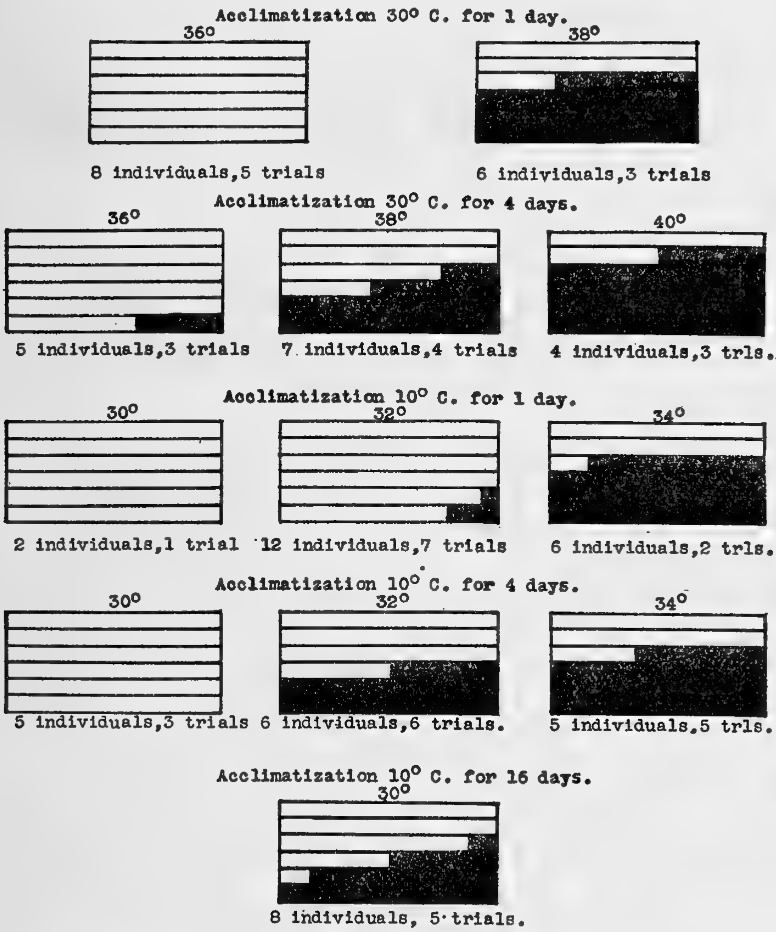

FIG. 2.—Effects of high temperatures on large-mouthed black bass that had been acclimatized to 30° C. or 10° C. For explanation of symbols see Figure 1

to invalidate the experiment. During the test periods any fluctuations of temperature, either upward or downward, were important. The normal variations were 0.2° to 0.3° C. They seldom were more than this, except when the apparatus was seriously out of order, and if at any time in a test the temperature was found to be as much as 1° above or below that specified the results were discarded. This rule was very important, because it was found that a drop of 1° or 2° for a short time during the early hours of a test apparently enabled a fish to become adjusted and to

survive when all other individuals tested under the same conditions had died; and, conversely, a rise of 1° for only a short time sometimes was followed by the death of fishes that normally would have been expected to survive.

So far as possible, uniform aeration was maintained, the streams of bubbles being controlled by the use of clamps on the rubber air tubes. A number of experiments in which it appeared that the deaths might have been due to weakness or stoppage of the aeration were discarded.

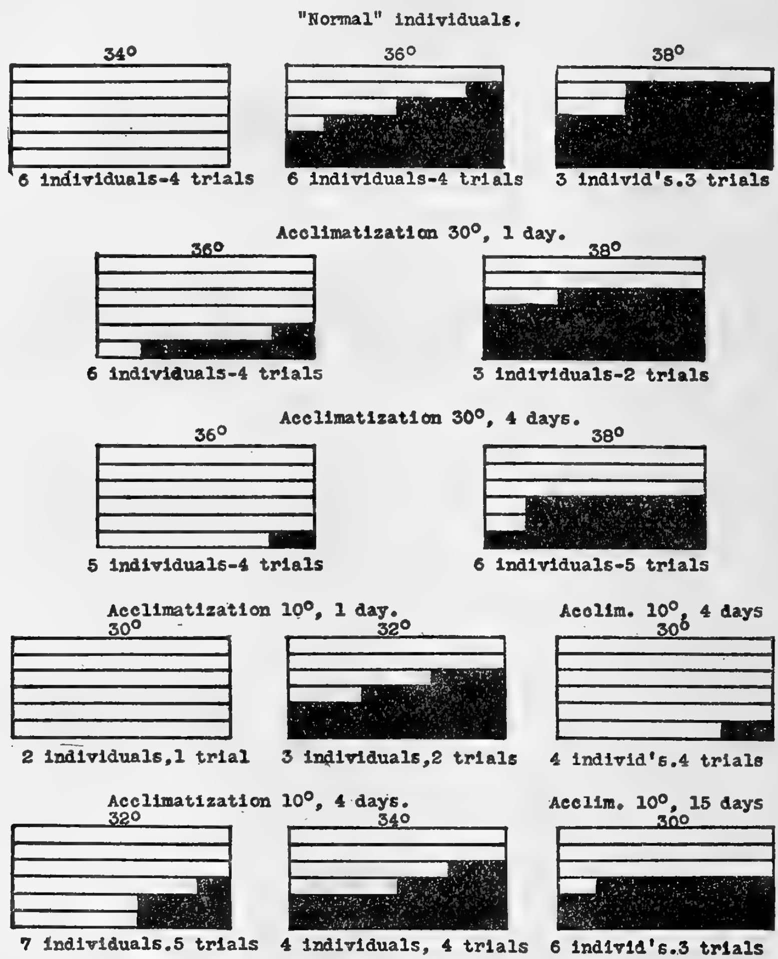

Fig. 3.—Effects of high temperatures on young bluegills. For explanation of symbols see Figure 1

NUMBER OF TRIALS

The term "trial" as used in this paper refers to a 24-hour test at a given temperature on the specimens in one container. The term "series" is used to designate the group of trials performed at a given temperature on similar individuals of the same species which had received the same preliminary treatment. The various trials in one series usually were made on different days, although in some instances

two of them were run simultaneously. The numbers of trials and individuals in the various series were very unequal, being small when all the individuals died quickly or survived easily and much larger at some crucial points in the experiments in which the results were seriously in doubt.

RECORDS

The record of each trial included (1) remarks on any peculiarities of the specimens at the beginning of the test (for example, size and condition), (2) temperature

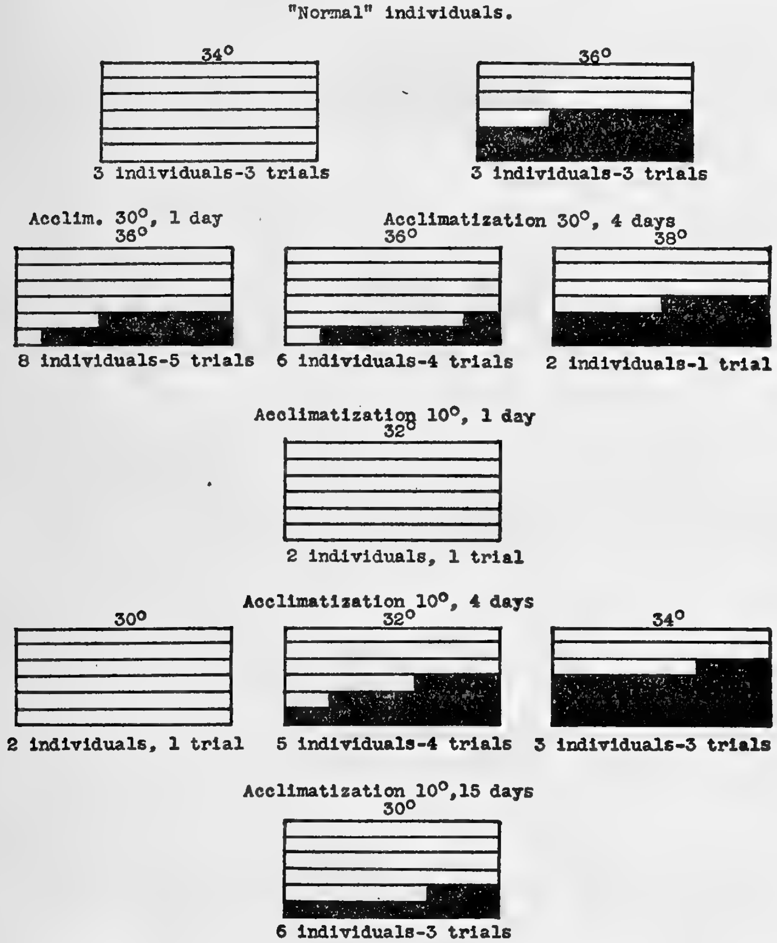

FIG. 4.—Effects of high temperatures on young sunfishes (pumpkinseed). For explanation of symbols see Figure 1

and exact duration of acclimatization, (3) notes on the behavior of the specimens immediately following transfer to the trial temperature, and (4) notations made at the time of each observation. The latter included a statement of the exact time at which the observation was made and a brief description of the condition of each of the specimens as indicated by its appearance and behavior, together with notations on any of the experimental conditions that seemed important.

RESULTS

The details of the results obtained in the work on yearling fishes and on toad tadpoles are shown diagrammatically in Figures 1 to 7. These diagrams present the results of 180 trials on a total of 247 fishes and 62 trials on a total of 181 tadpoles. These trials comprise 46 series on fishes and 24 series on tadpoles. In addition to the experiments represented in the diagrams, a relatively small number of trials was performed on mature sunfishes and perch and on perch, bluegills, and sunfishes less than 1 year old.

The figures given above include only experiments successfully completed under the conditions that have been described and at temperatures that seem to be significant in indicating the limits of tolerance of the animals. They are exclusive of a considerable number of trials conducted at temperatures that were found to be distinctly above or below the limits of tolerance of the species. Such trials were of some interest, however, in indicating the consistency with which, under the experimental conditions, a graded series of temperatures affected the animals.

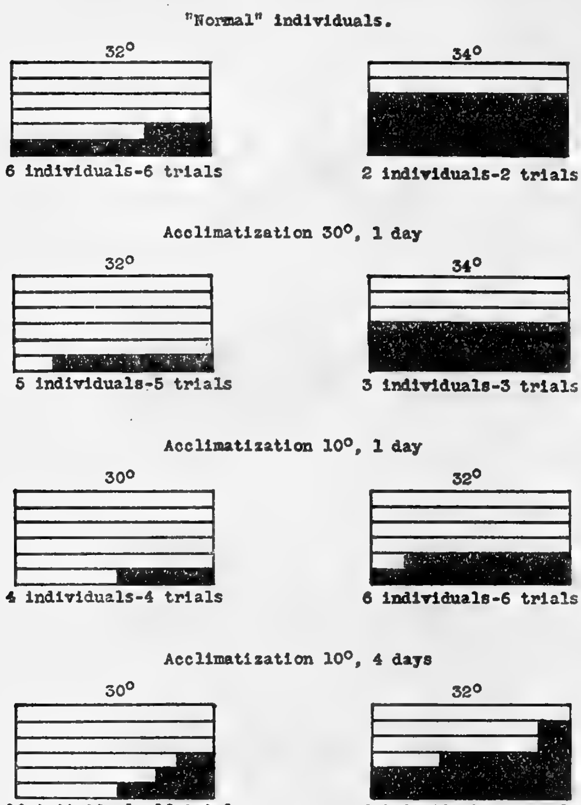

FIG. 5.—Effects of high temperatures on yellow perch. For explanation of symbols see Figure 1

LIMITS OF TOLERANCE IN NORMAL INDIVIDUALS

The results obtained with normal individuals of the five species of animals, which are summarized in Table 2 and in Figure 8, may be stated briefly as follows:

1. The perch, which is typically a dweller in fairly deep water, has decidedly the lowest resistance to high temperatures of any of the animals studied.

2. The large-mouthed black bass, bluegill, and sunfish, which are, in the main, shallow-water fishes, have resistances that are notably higher than that of the perch.

3. Toad tadpoles, which normally live in shallow pools that are subject to wide fluctuations in temperature, have a higher resistance than any of the fishes.

TABLE 2.—*Maximum temperatures, in degrees centigrade, tolerated for various lengths of time by normal individuals of different species*

Animal	24-hour tolerance	4-hour tolerance	1-hour tolerance	15-minute tolerance	4-minute tolerance
Perch	29.6	31.5	32.0	32.0	34.0
Bass	32.2	32.4	33.4	33.7	36.0 +?
Bluegill	34.0	34.0	34.3	35.7	36.4
Sunfish	34.0	34.0	35.3	36.0	36.0 +?
Toad tadpole	36.3	37.3	37.4	38.6	39.2

The following features of the data contained in Table 2 and Figure 8 seem worthy of mention:

1. In each species there was a perfectly orderly progression, from the relatively low temperatures that were tolerated for 24 hours to the higher temperatures, which could be survived for only four minutes.

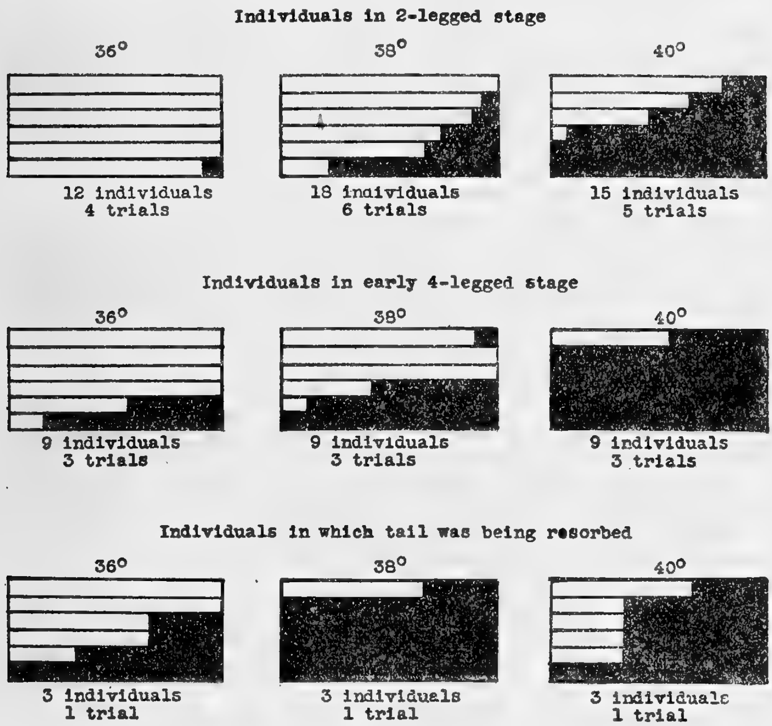

FIG. 6.—Effects of high temperatures on "normal" toad tadpoles in various stages of development. The symbols are the same as in Figure 1, except that the black sectors include individuals in heat rigor as well as those actually dead

2. For every time period, with one minor exception, the relative degrees of heat tolerated by the five species of animals fell in the same sequence—that is, the ascending order of tolerance was (*a*) perch, (*b*) bass, (*c*) bluegill, (*d*) sunfish, (*e*) toad tadpoles.

A few tests were made in the endeavor to determine the relation of age to tolerance of high temperatures. Perch 6 months old showed about the same resistance as those 18 months old, usually tolerating 30° C. (86° F.) but not 32° C. (89.6° F.).

In the work on fishes 2 or more years old the results were complicated by the fact that the volume of water in relation to the size of the fish was found to be an important factor in determining the temperatures survived. Two perch were tested at 30° C. in jars containing 2½ liters of water and two others in jars containing about 6 liters of water. Each of the fishes in the small jars died in a little more than one hour, while both of those in the large jars survived the 24-hour test in good condition. Similar results were obtained with mature sunfishes, death at 30° C. occur-

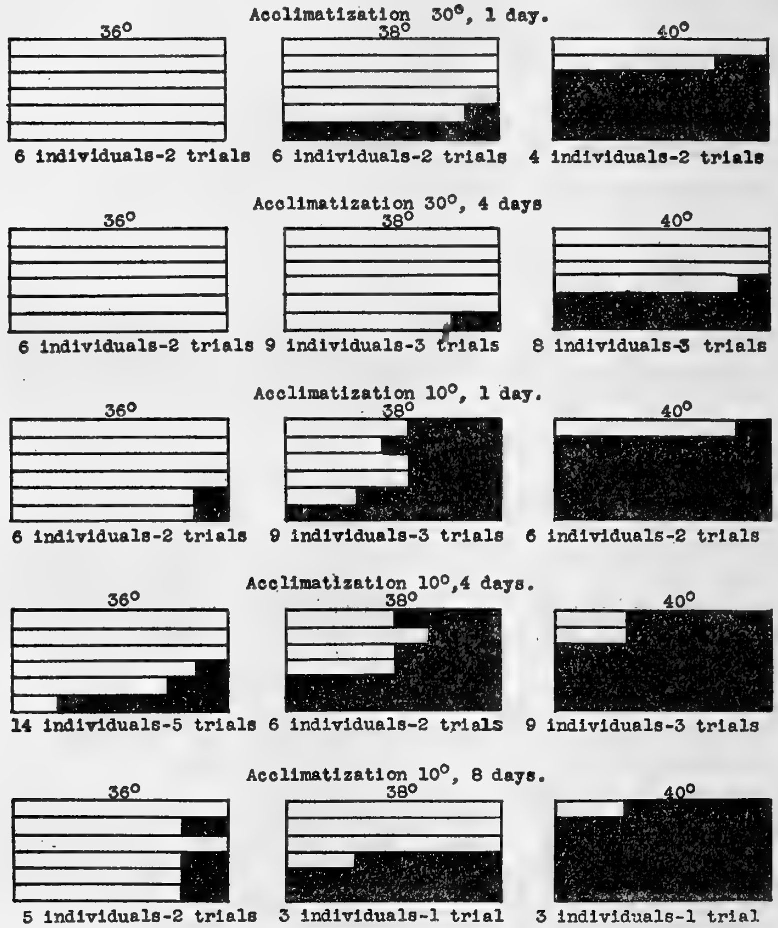

FIG. 7.—Effects of high temperatures on toad tadpoles that had been acclimatized to 30° C. or to 10° C. For explanation of symbols see Figures 1 and 6

ring in from 16 to 22 hours in the small jars, while the 24-hour test period was easily survived in the larger volume of water. It was found, however, that mature sunfishes could live for weeks, with infrequent change of water, in small jars at 30° C., after spending the first 24 hours at that tempertature in the larger container. These facts suggest that the dissolved content of the water may be of great importance as a cause of death of normal individuals if the volume of water is relatively small.

In tadpoles the results seem to indicate a definite relation between phases of the life cycle and temperature tolerance. For purposes of comparison, the tadpoles

used were divided into three classes—(1) those having hind legs in various stages of development but no visible front legs, (2) those having four legs visible but not yet beginning to resorb the tail, and (3) those in which the tail was being lost. Many times, in the work on the two-legged stage, young or retarded individuals were included in the same trials with those that were farther advanced in development, and there seemed to be no appreciable difference in heat tolerance between them; but about the time of the appearance of the front legs there was a sharp fall in the resistance, and this became still more marked as the tail was being resorbed. Evidence on this point was obtained by special trials conducted on individuals in the later stages of metamorphosis, the data being presented in Table 3 and Figure 6.

TABLE 3.—*Maximum temperatures, in degrees centigrade, tolerated for various lengths of time by normal toad tadpoles in various stages of development*

Stage of development	24-hour tolerance	4-hour tolerance	1-hour tolerance	15-minute tolerance	4-minute tolerance
Two legs	36.2	37.3	37.4	38.6	39.3
Four legs	34.2	35.1	36.9	38.0	38.0
Losing tail	34.0	34.7	35.3	35.3	36.0

To rule out asphyxiation as a possible cause of death of the most advanced individuals, solid objects were supplied on which they could crawl out and get air. The data indicate that for each of the five time periods the tolerance limits of the three stages of tadpoles fell in the same order—namely, two-legged individuals highest, early four-legged stage intermediate, and those losing their tails lowest.

MODIFICATION OF TOLERANCE BY ACCLIMATIZATION

In making determinations of tolerance on individuals that had been exposed to temperatures of 30° C. (86° F.) and 10° C. (50° F.) the same methods of procedure and computation were used as in the case of normal individuals. The details of the results are shown in Figures 2, 3, 4, 5, and 7 and in Tables 4 and 5, while Figure 9 compares the results secured with the various animals.

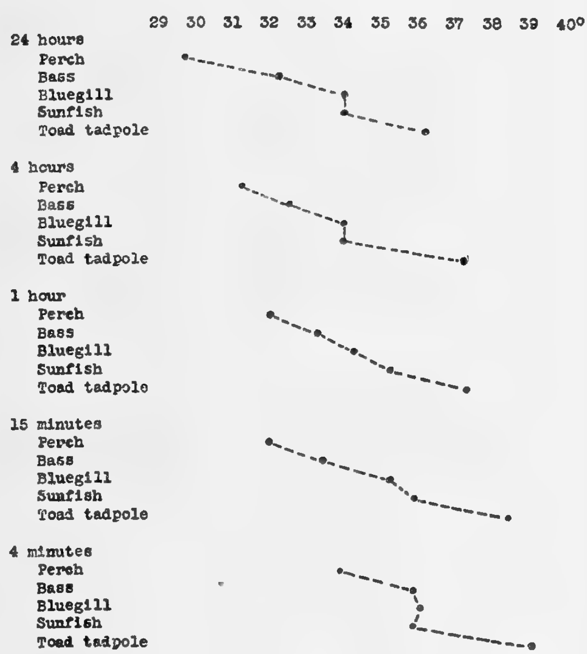

FIG. 8.—Averages of maximum temperatures tolerated for various lengths of time by normal individuals of different species. Complete data on tolerance of bass and sunfish for four minutes are not available. In both of these cases the tolerance may be a little greater than that shown

TABLE 4.—*Maximum temperatures, in degrees centigrade, tolerated for various lengths of time by normal individuals and by those that had been acclimatized for different lengths of time at 10° and 30° C. The signs +? or −? indicate that the limit of tolerance was shown to be as high (or low) as the figure given and was possibly higher (or lower)*

Temperature and duration of acclimatization	24-hour tolerance	4-hour tolerance	1-hour tolerance	15-minute tolerance	4-minute tolerance
Perch:					
30°, 1 day	30.3	32.0	32.0	34.0	34.0+?
Normals	29.6	31.5	32.0	32.0	34.0
10°, 1 day	29.0	30.3	32.0		
10°, 4 days	29.0	29.4	31.3	31.7	31.7+?
Bass:					
30°, 4 days	35.2	36.0	36.9	37.4	39.0
30°, 1 day	36.0	36.0	36.0	36.7	38.0
Normals	32.2	32.4	33.4	33.7	36.0+?
10°, 1 day	31.5	31.8	32.0	32.3	34.0
10°, 4 days	30.0	30.0	31.0	32.8	34.0
10°, 16 days	28.0−?	28.3	29.0	29.8	30.0
Bluegills:					
30°, 4 days	35.6	36.3	36.3	38.0	38.0+?
30°, 1 day	34.3	35.7	36.0	36.7	38.0+?
Normals	34.0	34.0	34.3	35.7	36.4
10°, 1 day	30.0	30.0	30.7	32.6	34.0+?
10°, 4 days	30.6	31.1	32.7	33.5	34.0+?
10°, 16 days	28.0−?	28.0−?	28.3	30.0+?	30.0+?
Sunfish:					
30°, 4 days	34.3	35.7	38.0		
30°, 1 day	34.2	34.8	36.0+?	38.0	38.0
Normals	34.0	34.0	35.3	36.0	36.0+?
10°, 1 day	32.0+?				
10°, 4 days	30.0	30.4	31.2	33.4	34.0+?
10°, 16 days	28.0−?	29.4	30.0+?		
Toad tadpoles:					
30°, 4 days	37.6	38.0	39.8	40.0+?	40.0+?
30°, 1 day	36.0	37.7	38.0	38.0	39.5
Normals	36.3	37.3	37.4	38.6	39.2
10°, 1 day	35.7	36.3	37.1	37.1	37.1
10°, 4 days	34.4	35.6	36.7	37.0	38.0

TABLE 5.—*Numbers of degrees centigrade by which tolerances of different species were modified by acclimatization at 30° and at 10° C. The data in this table represent the differences between the temperatures tolerated by normal and acclimatized individuals, as shown in Table 4*

Temperature and duration of acclimatization	24-hour tolerance	4-hour tolerance	1-hour tolerance	15-minute tolerance	4-minute tolerance
Perch:					
30°, 1 day	0.7	0.5	0.0	2.0	0.0
10°, 1 day	−.6	−1.2	.0		
10°, 4 days	−.6	−.9	−.7	−.3	−2.3
Bass:					
30°, 4 days	3.0	3.6	3.5	3.7	3.0
30°, 1 day	3.8	3.6	2.6	3.0	2.0
10°, 1 day	−.7	−.6	−1.4	−1.4	−2.0
10°, 4 days	−2.2	−2.4	−2.4	−.9	−2.0
10°, 16 days	−4.2	−4.1	−4.4	−3.9	−6.0
Bluegills:					
30°, 4 days	1.6	2.3	2.0	2.3	1.6
30°, 1 day	.3	1.7	1.7	1.0	1.6
10°, 1 day	−4.0	−4.0	−3.6	−3.1	−2.4
10°, 4 days	−3.4	−2.9	−1.6	−2.2	−2.4
10°, 16 days	−6.0	−6.0	−6.0	−5.7	−6.4
Sunfish:					
30°, 4 days	.3	1.7	2.7		
30°, 1 day	.2	.8	.7		
10°, 1 day	(?)				
10°, 4 days	−4.0	−3.6	−4.1		
10°, 16 days	−6.0	−4.6	−5.3		
Toad tadpoles:					
30°, 4 days	1.3	.7	2.4	1.4	.8
30°, 1 day	−.3	.4	.6	−.6	.3
10°, 1 day	−.6	−1.0	−.3	−1.5	−2.1
10°, 4 days	−1.9	−1.7	−.7	−1.6	−1.2

RESULTS OF EXPERIMENTS ON FISHES

The facts regarding fishes shown in Figure 9 may be summarized as follows: (1) The loss in tolerance by acclimatization at 10° C. was most rapid in sunfishes and bluegills, the species that have the highest normal resistance; it was less marked in the bass, and was decidedly the least in the perch, which has the lowest normal tolerance. (2) The gain in tolerance at 30° C. was rapid in the bass and relatively slow in the sunfishes, bluegills, and perch.

Four facts regarding the data on which these conclusions are based may be noted: (1) With a few exceptions (probably due to experimental error), the results indicate a continuous increase in tolerance by acclimatization at 30° C. and a continuous decrease at 10° C. (2) The tolerance limits determined for the different periods of time (24 hours, 4 hours, 1 hour, 15 minutes, and 4 minutes), involving, as they do, more than one set of individuals and more than one set of experimental conditions, serve as a check on each other and for the most part corroborate each other. (3) The percentage of results that are far off from the mode in any series is small. (4) Observations on behavior (which will be presented later), although hard to express in numerical terms, support the conclusions.

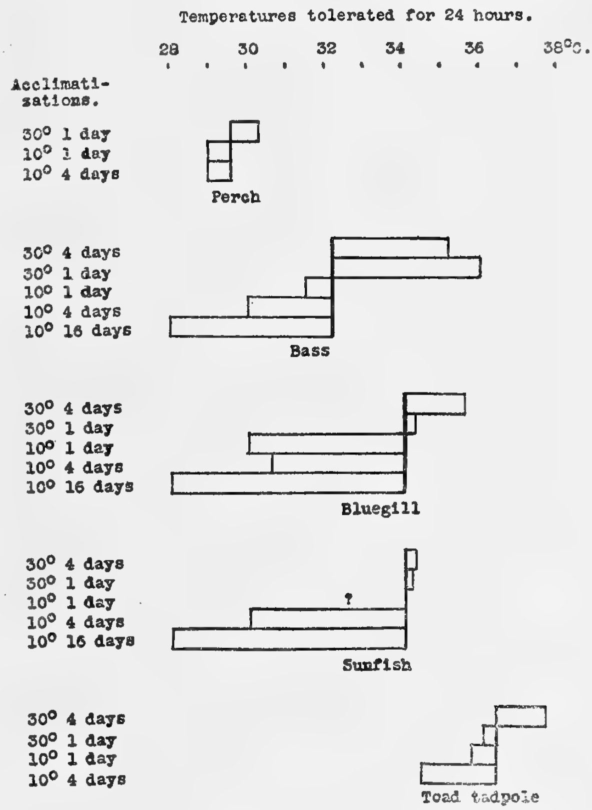

FIG. 9.—Extent to which acclimatization alters the tolerance of each species. The center line in each figure indicates the average tolerance limit of "normal" individuals. The lengths of the bars extending to the right show the average amounts of increase in tolerance produced by acclimatization; those to the left show decreases

Inasmuch as the initial tolerance of bluegills and sunfishes was relatively high (34° C.; 93.2° F.) and their gain in tolerance by acclimatization at 30° C. quite slow, it seemed possible that their gain in tolerance was slow because the acclimatization temperature of 30° was not high enough to evoke a vigorous reaction. This appeared the more probable because Loeb and Wasteneys (1912) secured their greatest changes in tolerance by exposing fishes, for short periods of time, to very high temperatures; so it was thought desirable to determine the effect of acclimatization at the tolerance limit of each species.

Accordingly, bass, bluegills, and sunfishes that had been at 30° C. for one day were exposed to 36° C. (96.8° F.), their tolerance limit, and then tested at higher temperatures. It was found that one day at 36° enabled the bass to tolerate 38° C. (100.4° F.) for 24 hours or more; while four days' acclimatization was required to produce the same results in bluegills and sunfishes. These results indicate that the tolerance of bluegills and sunfishes can be raised substantially if a high enough temperature is used in acclimatization, but they also furnish confirmatory evidence of of the still greater modifiability of the bass. When, in this connection, it is recalled that the acclimatization temperature of 30° C. (86° F.) (which was the only one used for the perch) was the normal tolerance limit of the species, the conclusion that the perch is the least modifiable of the animals studied seems to be confirmed.

MODIFICATIONS OF TOLERANCE IN TOAD TADPOLES

The detailed results obtained with tadpoles are shown in Tables 4 and 5 and in Figures 7 and 9, in which it appears that the changes in tolerance were clearly marked but slow. Exposure to 30° C. (86° F.) for 24 hours produced no significant change in resistance; while in 4 days at 30° C. the gain in tolerance was less than half that shown by the bass.

As in the case of bluegills and sunfishes, the slowness of the gain in tolerance appears to be due, at least in part, to the fact that the acclimatization temperature of 30° C. was too far below the normal tolerance limit to be very effective. This view was supported by several tests. Fifteen individuals in five different lots were exposed for one day to a temperature of 36° C. (96.8° F.) their tolerance limit. They were then tried at 38° C. (100.4° F.), and all but one survived for 24 hours. On being transferred to 40° C. (104° F.), however, all died. These results seem to indicate that one day at 36° C. was as effective in raising the resistance of tadpoles as four days at 30° C., and that the capacity of tadpoles for increase of tolerance is not very different from that of bluegills and sunfishes.

The most distinctive feature of the results obtained with tadpoles is the slowness with which resistance was lost through exposure to low temperature. It will be recalled that in those species of fishes having the highest normal resistance there was a rapid lowering of the tolerance limit by exposure to 10° C. (50° F.), while in the species having low normal resistance the decrease in tolerance was slow. Tadpoles, on the other hand, with a normal resistance 2.3° higher than that of any of the fishes, lost tolerance more slowly than any of the fishes except the perch. Table 6 brings out this contrast.

TABLE 6.—*Relation between normal tolerance limits of different species and the number of degrees centigrade by which the tolerance limit was lowered by exposure to 10° C. for four days*

Species	Normal 24-hour tolerance limit	Amount of lowering of tolerance limit
Perch	29.6	0.6
Bass	32.2	2.2
Bluegill	34.0	3.4
Sunfish	34.0	4.0
Toad tadpole	36.3	1.9

BEHAVIOR AT HIGH TEMPERATURES

Observations on the behavior and apparent condition of the experimental animals, while difficult to reduce to quantitative terms, are of some interest because they support, in some important respects, the conclusions drawn from the data on survival, and they give some clues as to the nature of the acclimatization process. Three effects commonly followed the transfer of normal fishes to high temperatures:

1. Increase in general activity.
2. Disturbances of equilibrium such as (*a*) elevation of the tail, so that the body stood at an angle of from 30 to 90° to the horizontal; (*b*) a persistent tendency of the fish to rise to the surface, tail first, constant use of the fins being required to keep the fish at the bottom; (*c*) a rolling from side to side, or rotation on the longitudinal axis; (*d*) floating at the surface.
3. Increase of respiratory movements. Sometimes there was merely an increase in respiratory rate, but in other cases there was also an increase in amplitude of respiratory movements, so that breathing was labored, the fishes often coming to the surface to gulp air.

The disturbance of equilibrium usually occurred within 1 to 4 minutes after the fishes were transferred to the higher temperature, although sometimes it was delayed longer, while the increase in respiratory movements usually became pronounced within the first 15 minutes of the test. In cases where the fishes survived the 24-hour test, normal equilibrium usually was regained in from 1 to 4 hours, while the labored breathing commonly disappeared in from 4 to 20 hours. The original rate of respiratory movements seldom, if ever, was regained during the 24-hour test period.

The extent to which the effects described were manifested by normal fishes varied greatly, according to the test temperatures, and the description that follows represents the usual results in all the species except the perch.

1. At the highest temperature that most of the normal individuals could tolerate for 24 hours there was some disturbance of equilibrium and respiration, followed by complete recovery.
2. At a temperature that a minority of the individuals could survive there was marked initial disturbance of equilibrium and respiration. This was followed by complete recovery in some cases; in other cases equilibrium was regained temporarily, but death occurred several hours later; in still others there was no recovery.
3. At a temperature that none of the individuals could survive there was great disturbance of both equilibrium and respiration, with no signs of recovery except, perhaps, temporary improvement in equilibrium.

The behavior of perch resembled, in a general way, that of the three other species, but their recovery of normal respiration was slower. A bass, when placed at 32° C. (89.6° F.), or a bluegill or sunfish at 34° C. (93.2° F.), their respective limits of tolerance, usually resumed light, easy breathing within 10 to 12 hours; while a perch placed at 30° C. (86° F.), its limit of tolerance, often would continue noticeably labored respiratory movements for two or three days. These facts apparently support the conclusion, previously reached, that the perch has the least power of adjustment to increases in temperature of any of the fishes studied.

The disturbances in equilibrium and respiration occurring within the first 15 minutes of a test are referred to as the "initial shock." Table 7 summarizes the

observations on initial shock and the subsequent effects in normal and acclimatized bass tested at their tolerance limits and at temperatures above these limits. The following facts, which appear in Table 7, are fairly typical of what was observed in all the species of animals:

1. Acclimatization at 10° C. (50° F.), and 30° C. (86° F.) not only changed the limits of tolerance of fishes but also changed their behavior at high temperatures.

2. Acclimatization at 30° C. greatly reduced the initial shock, even at temperatures at which many individuals eventually died. Individuals that did show shock effects rarely survived.

3. Acclimatization at 10° C. greatly increased initial shock, and large numbers of individuals, after showing great disturbance of equilibrium and respiration, were able to make at least a temporary recovery.

TABLE 7.—*Incidence of and recovery from initial shock in large-mouthed black bass; the figures in the table refer to percentages of individuals*

Acclimatization	Test temperatures, ° C.	Showed no shock effects		Showed shock effects					
				Recovered normal equilibrium and respiration		Recovered normal equilibrium but not respiration		No apparent recovery	
		Lived	Died	Lived	Died	Lived	Died	Lived	Died
Normals	32	0	0	100	0	0	0	0	0
	34	0	0	26	0	0	20	0	54
	36	0	0	0	12	0	0	0	88
30°, 1 day	36	88	0	12	0	0	0	0	0
	38	0	17	0	17	0	0	0	66
30°, 4 days	36	0	0	60	40	0	0	0	0
	38	0	57	0	0	0	0	0	43
10°, 1 day	30	100	0	0	0	0	0	0	0
	32	0	0	75	0	0	25	0	0
	34	0	0	0	0	0	0	0	100
10°, 4 days	30	0	0	100	0	0	0	0	0
	32	0	0	0	0	0	83	0	17
	34	0	0	0	0	0	40	0	60
10°, 16 days	30	0	0	0	0	0	40	0	60

The results obtained with tadpoles paralleled fairly closely those obtained with fishes. While there was not the tendency to rise to the surface, which was noticed in fishes, the loss of equilibrium often was very pronounced. The increase in temporary initial shock by acclimatization at 10° C. was clearly noted, several individuals (fig. 7) being observed to go into heat rigor within the first few minutes of a test and resume normal movement before the end of the first hour.

The significance of the shock effects is not clear. The loss in equilibrium and tendency to rise to the surface, which was noted in fishes, resembled the behavior noted by Hall (1924) in fishes that were subjected to high concentration of CO_2 and low concentrations of oxygen. Whether the effect was due to the secretion of gas into the swim bladder, or simply to the expansion by heat of the gas already there, seems uncertain. In any case, the loss of equilibrium does not appear necessarily to be closely connected with the immediate cause of death of fishes or tadpoles, as death often occurred several hours after complete recovery of equilibrium.

DISCUSSION

Before taking up a discussion of the results obtained, some possible complicating factors in the experiments will be considered. In the first place, it may be asked whether the methods used constitute an adequate test of the temperature tolerance of the animals. Ideal procedure might, like the methods of Dallinger (1880) and Jollos (1921), working with microorganisms, test the ability of an animal to reproduce at a given temperature, but obviously such a method was impracticable in the present instance. Thermal death points have been employed in various ways by different experimenters. The method of Davenport and Castle (1895) involves the cumulative effects of a series of increasing temperatures; and as some animals succumb very quickly when an injurious temperature is reached, while others linger for some time in a dying condition, the use of steadily increasing temperatures does not seem to afford a very satisfactory means of comparing the thermal death points of different animals. Loeb and Wasteneys (1912) measured tolerance in terms of the number of minutes that their fishes survived at a given temperature; and while this method seems quite satisfactory in theory it is difficult to apply in a long series of experiments, as its accurate use would necessitate observations at frequent intervals throughout both day and night. In the present experiments the use of fixed time periods and several constant temperatures made it possible to determine the maximum temperature tolerated for each of the time periods, these maximum temperatures serving as checks on each other.

The desirablility of continuing the tests for more than 24 hours was considered, because it was realized that survival for one day at a given temperature does not necessarily imply the ability to tolerate it indefinitely. There was strong objection, however, to lengthening the experiments, as Saprolegnia often develops on the fishes very rapidly at or above 30° C, and a slight growth of this fungus seems to reduce materially their resistance to high temperatures. Then, too, at the end of a 24-hour test most of the individuals were either dead or apparently in good condition, so it was thought that the one-day period afforded a reasonably satisfactory basis for comparison with minimum likelihood of the introduction of complicating factors.

The question also may be asked whether any of the results noted can have been due to selection. There were only two points in the handling of the fishes before the test periods at which there were significant numbers of deaths. The first was the time when the fishes were brought into the laboratory, when a considerable mortality occurred among yearling fishes. The deaths at this time apparently were due to the shock of handling, and not to temperature, as almost all the perch (which are quite sensitive to heat, poor aeration, and foulness of the water) survived the transfer, while the young bluegills, which are much more resistant to heat and foulness of water than the perch, suffered a mortality of more than 50 per cent. The sunfishes stood the change considerably better than the bluegills, while the loss among bass was probably less than 5 per cent. The deaths of older fishes, following transfer, were negligible. The other case where deaths occurred to a notable extent was during the acclimatization of perch at 30° C. As this selection during acclimatization might have been expected to raise the average resistance of the survivors, it merely serves to emphasize the fact that the perch has relatively little capacity for increase in tolerance.

The precise cause of death at high temperatures is an important question, to which only a partial answer can be made at present. Mayer (1917) considers that it is due mainly to accumulation of acid in the tissues. The work of a number of investigators has shown that several factors, some external and some internal, may be involved. Loeb and Wasteneys (1912) showed that slight changes in the salinity of the surrounding water caused marked changes in the temperature tolerance of Fundulus. The importance of dissolved oxygen and carbon dioxide as limiting factors in the life and distribution of fishes has been stressed by several writers (Juday and Wagner, 1908; Birge and Juday, 1911; Wells, 1913 and 1915; and Pearse, 1918). That hydrogen-ion concentration is an important factor in the tolerance of low oxygen tensions by fishes is maintained by Wells (1913 and 1915). The influence of pH on the distribution of fishes has been pointed out by Shelford (1923) and Coker (1925); while the work of Shelford and Allee (1913), Shelford and Powers (1915), and Powers (1921) indicates that many (but not all) fishes can discriminate between different degrees of acidity and show definite positive and negative reactions to pH gradients. It appears that there is a good deal of difference between the pH preferences of various species, and the observations of Miss Jewell (1922) indicate that the reactions of individual fishes to pH may be modified by acclimatization.

There is a considerable amount of evidence to the effect that changes in the composition of blood of fishes may play a large part in survival under unfavorable conditions. Packard (1905, 1907, and 1908) materially lengthened or shortened the survival time of Fundulus in oxygen-free water by injections of sodium carbonate, acetic acid, or other substances. Birge and Juday (1911) suggested that if a fish were able to change the alkali reserve of its blood it would better be able to tolerate oxygen deficiency; and this theory is supported by Powers (1922 and 1922a), who has secured evidence indicating that the ability of fishes to absorb dissolved oxygen varies with the pH of the water, but that the effect is relatively slight in cosmopolitan fishes. Krogh and Leitch (1919) showed that the blood of carp, pike, and eels can unload oxygen at lower oxygen tensions than can the blood of trout and some marine fishes.

In the present experiments the changes from low to high temperatures necessarily involved changes in concentration of dissolved oxygen; and from the literature cited it appears that in many cases the death of fishes at high temperatures must be regarded as the result of the combined action of a number of factors, some internal and some external. However, the strong aeration in these experiments was designed to reduce to a minimum the fluctuations in oxygen and carbon dioxide tension during the tests, and there are two reasons for beleiving that temperature was the limiting environmental factor in the tolerance of the animals tested:

1. While the death symptoms commonly seemed to indicate asphyxiation, this appeared to be due to internal rather than external causes. Of two fishes in the same jar, frequently one would be dying (apparently from asphyxiation), while a similar individual, which had received the same preliminary treatment, would be breathing easily and would survive in good condition.

2. The results obtained in the 4-minute and 15-minute test periods, in which there was very little opportunity for change in the dissolved content of the water, ran almost perfectly parallel with the results obtained in the longer test periods.

Forbes and Richardson (1908), Everman and Clark (1920), Pearse and Achtenberg (1920), and Pearse (1921) agree that perch are to be regarded as typically lake fishes, with a decided preference for deep, cool water. When obliged to desert the deepest parts of a lake on account of summer stagnation, perch remain, for the most part, at the bottom in the region of the thermocline (Pearse and Achtenberg, 1920). It was not surprising, therefore, to find that normal perch had a low limit of temperture tolerance and relatively little ability to become adjusted to higher temperatures. Neither did it seem strange that such resistance as the perch did possess was very slightly reduced by exposure to a temperature of 10° C. The large-mouthed black bass, sunfish, and bluegill, on the contrary, are to be regarded as typically shallow-water fishes (Pearse, 1921). They were collected in large numbers from waters 3 to 5 feet deep, in places where abundance of aquatic vegetation impeded circulation of water, so that the temperature often was considerably higher than that of most of the surface of the lake. Sunfishes, indeed, seldom are found in waters without vegetation (Pearse, 1921). The results in the present experiments seem to indicate a correlation between the high temperatures occurring in the shallow portions of a lake and a high degree of tolerance and modifiability possessed by the fishes that usually inhabit these waters.

It is doubtful, however, whether differences in tolerance and in capacity for acclimatization are explainable wholly on ecological grounds. It is of interest to note that bluegills and sunfishes (which are closely related in taxonomic position and have similar but not identical habitat preferences) showed the same normal limit of tolerance and practically the same degree of modifiability. Bass, on the other hand, with habitat preferences quite similar to those of the other centrarchids, appeared to have a limit of tolerance distinctly lower than that of the bluegills and sunfishes, but a greater capacity for rapid increase in resistance by exposure to high temperatures. Although all three species of shallow-water fishes suffered rapid reduction in tolerance by exposure to low temperature in the laboratory, this change might be expected to occur only very slowly in a state of nature because of the relative slowness of fluctuation in the temperature of a lake.

The conditions of life of toad tadpoles are somewhat different from those of fishes. The shallow pools that they commonly inhabit present the possibilities of wide diurnal fluctuations in temperature and of protracted chilling during periods of cool, cloudy weather. As previously noted, the present experiments seem to indicate that normal tadpoles have a very high tolerance limit, with moderate capacity for further increase in resistance, while their loss of tolerance at 10° C. is relatively slow. When it is recalled that, among fishes, high tolerance limits were subject to rapid lowering by exposure to cold, the possession by tadpoles of a very high and relatively stable degree of tolerance appears to be a distinct adjustment to the variable temperature conditions under which they live.

Regarding the physiological nature of the changes involved in acclimatization, little that is new can be said at present. Evidence secured by Davenport and Castle (1895) and by Loeb and Wasteneys (1912) indicates that resistance to high temperatures gained by acclimatization is lost very slowly even at very low temperatures, and several observations to the same effect were made on both fishes and tadpoles in the course of the present work. The heavy breathing of fishes transferred to high

temperatures, indicative of increased respiratory metabolism (Gardner and Leetham, 1914 and 1914a; Rubner, 1924), was followed by a return to nearly normal breathing as the fishes became adjusted to their new environment. This suggests that acclimatization involves either an increase in the ability of fishes to absorb dissolved oxygen, or a decrease in metabolic rate, such as was observed by Miss Behre (1918) in Planaria. Experiments to test the latter possibility are now in progress.

SUMMARY

1. The maximum temperatures tolerated for 24 hours by normal animals belonging to five different species were found to be as follows: Perch, 29.6° C. (85.3° F.); large-mouthed black bass, 32.2° C. (90° F.); bluegill, 34° C. (93.2° F.); sunfish, 34° C. (93.2° F.); toad tadpole, 36.3° C. (97.3° F.). For the most part the tolerance limits of the different species are correlated with the temperatures to which they are exposed in their normal habitats.

2. Within each species individuals of different ages appeared to have about the same limits of tolerance, except in the case of tadpoles, which underwent a marked loss of resistance during the later stages of metamorphosis.

3. Continued exposure to high or low temperatures progressively raised or lowered the limit of tolerance of each species.

4. The fishes that inhabit shallow water (bass, bluegill, and sunfish) underwent a change of tolerance by acclimatization much more readily than the perch, which is typically an inhabitant of deep, cool water.

5. Some of the minor differences in tolerance and in modifiability of resistance among the various species of fishes seem to be specific, showing no apparent correlation with ecological factors.

6. Toad tadpoles differed from the fishes studied, in that, while having a very high limit of tolerance, their resistance to heat was reduced very slowly by exposure to low temperature.

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NATURE AND EXTENT OF FOULING OF SHIPS' BOTTOMS

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CONTENTS

INTRODUCTION

STATEMENT OF THE PROBLEM

Fouling of ship's bottoms is an accumulation of plant and animal organisms, which attach and grow on both wooden and metal ships. This accumulation of material consists of many species of animals and plants, which find the bottom of a vessel a favorable place of abode. All who have ever been at a seacoast have noted the crowded growths of "seaweed," barnacles, "moss," corals, and the like that frequently cover almost all structures that are either totally or partially submerged and that afford a place of attachment. It is this type of growth, in the main, that attaches to the hulls of boats and causes them to be "fouled." In its broadest usage, this word covers not only the effects of organisms that grow on ships, but also of those that burrow into them (in the case of wooden vessels), and has even been used to include the deleterious effects of corrosion on metal ships. In this paper only the first and original idea of this term will be considered, inasmuch as

the effect of marine borers recently has been studied extensively by others (Atwood, 1924), while the problem of corrosion has but little relation to this biological study.

The economic importance of the fouling of ships' bottoms rarely is realized by anyone who is not informed regarding the very special problems relating to the maintenance of ships. The factors that contribute to the importance of this problem may be outlined briefly, as follows:

1. Speed diminished up to 50 per cent.
2. Voyage delayed from 10 to 50 per cent of total time.
3. Increase in fuel consumption up to 40 per cent additional.
4. Increase in wear and tear on machinery.
5. Necessity for dry docking, cleaning, and painting after every six or eight months.
6. Loss of time for above, amounting to about one month out of every year.

It has been estimated conservatively that more than $100,000,000 is spent annually by the shipping interests of the United States alone because of fouling. When one realizes that fouling often increases the resistance of a ship in water, so that the fuel consumption must be increased 30 per cent in order to maintain a given speed, and that for more than half of the time between dry dockings for any vessel that operates at sea, after the first month, such costs probably are increased by a minimum of 10 per cent, the expense due to increased fuel consumption alone assumes large proportions.

It is the practice of most shipping concerns to "clean" the bottoms of their vessels every six or eight months. In order to do this the bottoms are exposed to view, either by the use of dry docks or marine railways. The former are of two types—the graving dry dock and the floating dry dock. Lighter craft frequently are removed from the water by a marine railway. The cost of maintaining and operating such equipment can be charged largely to fouling. The large sums of money involved can be realized when one learns that it costs approximately $100,000 to dry-dock, clean, and paint the bottom of a vessel such as the *Leviathan* or the *Majestic*, for these ships have more than an acre of surface exposed to the action of the sea and which must be cleaned and painted every time these vessels are dry-docked. It must not be forgotten, also, that during the period in dry dock the cost of maintaining the ship and its crew remains constant, while the operating income is reduced to nothing. The time spent in dry dock varies with conditions from three days to three weeks, or more; but for the ships listed in this report the average is seven or eight days. This process of cleaning is illustrated in Figure 1.

In addition to its economic importance, this problem has an important relation to the question of national defense. An able Navy has long been held to be the greatest force for defense that a country such as the United States can possess. Under present conditions, speed of such vessels is of increasing importance. If, then, fouling decreases the speed by as much as 40 per cent, the efficiency of such crafts is lost and critical delays might result.

From a biological point of view, this problem has several interesting aspects. The ecology of the organisms that live at some depth in the ocean has been difficult to study, because it has been impossible to bring them to the surface in sufficient

Fig. 1.—Process of cleaning the hull of a ship after dry-docking. The U. S. S. *Owl* at the Norfolk Navy Yard, June 6, 1925

numbers accurately to determine their relations as life communities. When, however, the bottom of a ship is raised out of water, these communities, in their entirety and uninjured, can be seen and qualitative and quantitative studies can be made. The effect of depth in producing distinct zonations may be studied easily on ships' bottoms, and these special groups of organisms can be studied thus in detail.

The study of this problem also presents data for the solution of the problem of geographical distribution. It has long been a debated question whether a given species of barnacle or other organism attached to the bottom of a boat can survive transportation to another port and continue to live and reproduce its kind. Whether one can explain the mundane distribution of some species of organisms in this manner never has been determined.

Data have been obtained that have a specific bearing on the question of the effect of pollution in our harbors and the ability of some types of organisms to survive. The rate of growth of different kinds of organisms can be studied from these data, as can also the problem of seasonal variation in their abundance. The effects of various poison paints, of sunlight, temperature, salinity, and of tidal currents are all of interest in a biological study of this problem and have been considered wherever possible during this investigation.

The author was assisted in the examination of ships by F. A. Varrelman and in some of the experimental studies by R. H. Luce. To the authorities of the Bureau of Fisheries and of the United States Navy, as well, and especially to Capt. Henry Williams, he is very grateful for many courtesies and continued interest in this work. For the use of laboratory facilities during the course of this investigation he is grateful to the directors of the zoological laboratory of the Johns Hopkins University, of the United States Fisheries laboratories at Woods Hole, Mass., and Beaufort, N. C., and of the biological laboratory of the Western Reserve University at Cleveland, Ohio.

HISTORY OF THE PROBLEM

The problem of fouling growths on the hulls of ships naturally is not a new one, for fouling has occurred ever since ships first were used. We seem to have no record regarding the earliest methods of prevention, but Atheneus (200 B. C.), quoted by Ewbank, informs us that "the ships of Archimedes were fastened everywhere with copper bolts and the entire bottom [of wood] was sheathed with lead." Alberti [in his work on architecture, published in the fifteenth century] tells us that a ship called "Trajans ship" was salvaged from Lake Riccia, where it had been submerged for more than 1,300 years, and that "over all, there was lead, fastened on with copper nails."

Young (1867) records the fact that a Roman ship, sunk in the Lake of Nemi, was found to have been coated with bitumen, over which sheets of lead had been nailed. The seams of the vessel were caulked with "tow and pitch," the hull being made of larch wood. In the reign of Henry VIII (1510 to 1547) vessels were covered with a coating of loose animal hair, attached over pitch, over which a sheathing board about an inch in thickness was fastened to keep the hair in its place. In the reign of Charles II (1660 to 1685) "the *Phoenix* and 20 other of His Majesty's ships were sheathed with lead and fastened with copper nails." That these methods were not satisfactory

is seen from the fact that none has persisted, for we find that during the eighteenth century the sheathing generally in use "was a doubling of the skin of a ship with wood, which was kept constantly payed with tar and grease, or mixtures of such compounds."

The prevention of fouling, then, has been a problem persisting through the centuries, which has taxed the skill of ingenious sea captains for hundreds of years; and the fact that it still occurs indicates the extremely difficult nature of its solution. In earlier times it was the general practice for vessels to be cleaned by the scouring action of the surf. A favorable beach was selected and the vessel carefully beached in such a manner that the surf, loaded with sand and broken shells, would scour the sides of the vessel and rid it of its fouling materials. Other vessels were run into fresh water at frequent intervals (a method still employed to a limited extent) and the organisms normally living in salt water would die and in some instances fall off, thus ridding the hull of its fouling. More recently the vessels were beached at flood tide and, allowing the vessel to list as the tide ebbed, were cleaned as the water would leave the vessel high and dry.

It has been the goal all along, however, to prevent the attachment of these organisms. That many people have been interested in this problem is indicated by the fact that in England, previous to 1865, according to Young (1867), more than 300 patents had been issued for antifouling materials; while in America 166 patents were issued prior to 1922, as found by Gardner (1922). The following quotation from his paper (p. 43) will serve to give some idea of the great variety of materials that have been employed within the last century.

> Amongst the many materials for prevention of fouling and corrosion of iron ships which have had patents taken for their use or been experimented with will be found silicates, quicksilver, plumbago, gutta percha, asphalte, shellac, guano, cow dung; now comes a powerful compound consisting of "clay, fat, sawdust, hair, glue, oil, logwood, soot, etc.," mixed, "to be plastered on the ships' bottoms"; then we have "emery, shellac, and castor oil"; next "pitch, tar, and shellac"; next comes another peculiar mixture, "baryta, litharge, arsenious acid, asphaltum, oxide calcium, and creosote"; than another, "Burgundy red earth, grease, lime, unburnt earthenware, chalk, or Roman cement." Next follows a very curious composition consisting of "grease from boiled bones, kitchen stuff, and butter without salt, mixed with poisonous materials." Now we have the grand chef-d'oevre of the whole, which is described thus: "Sugar, muriate of zinc and copper, and the sirup of potatoes or sugar with powdered marble quartz or feldspar." The last one, which will be noticed consists of "asafoetida with pitch, tar resin, and turpentine smeared over the bottom, and then coated with paper or cloth." Who will say, after this, that poisoning and physicking have not had their fair chance?

More modern methods, however, have centered around the idea of poison paints, for with the advent of iron ships the use of metals as sheathing was rendered impossible because of the electrolytic action in sea water and the consequent disintegration of the iron of the ship. Many types of antifouling paints containing posions are offered under various trade names, but none has yet been found which is satisfactory under all conditions. Indicative of the types of many of these paints are the two following, used by the Navy as its standard antifouling compositions in 1922 and 1925, respectively:

1922 NAVY STANDARD ANTIFOULING PAINT (Per gallon of paint)	1925 NAVY STANDARD ANTIFOULING PAINT (Per gallon of paint)
2,248 cubic centimeters denatured ethyl alcohol.	1,196 grams mineral spirits.
355 cubic centimeters pine tar oil.	306 grams pine oil.
355 cubic centimeters turpentine.	564 grams coal tar.
680 grams gum shellac.	923 grams resin.
680 grams zinc oxide, dry.	923 grams zinc oxide.
680 grams iron oxide.	616 grams iron oxide.
336 grams mercuric oxide.	410 grams mercuric oxide.
	515 grams cuprous oxide.
	329 grams silica.

Even before the use of steel ships, methods employed to limit the extent of fouling made use of various paints, many of which contained copper and mercury as poisons. In reviewing the methods followed until recently for the prevention of fouling one can not but be impressed with the fact that these methods have been governed largely by haphazard experiment and rule-of-thumb procedure. Precedence apparently has been relied upon more than any analysis of the factors involved. Progress under these conditions naturally is a matter of tardy development and slow improvement. Consequently, in an attempt to obtain more efficient paints the United States Navy has undertaken an extensive investigation of the entire problem, using a great variety of posions in as many paints. It was soon realized, however, that a careful study of the organisms responsible for the foul condition would be of considerable value, and at the request of the Navy Department, and with its support, this investigation of the fouling agencies has been made under the direction of the United States Bureau of Fisheries.

Although foul conditions on the bottoms of ships have been studied for many years, such studies have related almost entirely to the effects of fouling and to means of preventing it. Thus we find treatises such as that by Young (1867) on "The Fouling and Corrosion of Iron Ships," and many articles, from time to time, in transactions of such organizations as the British Institute of Naval Architecture and the American Society of Naval Architects and Marine Engineers. One of the most recent and comprehensive of such papers is entitled, "Notes on Fouling of Ships' Bottoms, and the Effect on Fuel Consumption," by Capt. Henry Williams, C. C., U. S. N. (1923). Many articles dealing with the effect of fouling, especially with its relation to resistance, have appeared in these journals (McEntee, 1915), but these have not concerned the nature or extent of fouling.

The growths on the bottoms of ships have been studied by many naturalists interested in collecting rare species of organisms and in systematic studies of various groups of animals and plants. Thus, Charles Darwin (1853) and H. Pilsbury (1916), in their respective treatises on barnacles, both record many of their specimens as having been secured from ships' bottoms.

At the time this investigation was begun (September, 1922) no study was known that dealt with the nature and extent of these growths. Since that date, however, two articles by Hentschel, working at Hamburg, have appeared, which

deal with "Growths on Marine Vessels." The former (1923) is an ecological study based on the examination of 48 vessels, while the second (1924) is a preliminary study of seasonal distribution of the organisms that cause fouling of ships, made while on board a vessel cruising from Hamburg to the West Indies and Central America.

METHODS

In order to determine adequately the nature and extent of fouling of ships on the Atlantic coast, it was arranged that the author be notified of the proposed dry docking of all the larger naval craft at several of the United States navy yards, and also by the United States Shipping Board regarding many of their vessels. This enabled the author or an assistant to be present at the time of docking of more than 250 vessels. Notations were made in each case of the relative amount of fouling and its distribution on the various parts of the hull. Collections of representative samples were made, which were preserved and carefully examined later in the laboratory. Since the material was frequently in a very poor condition when collected, due, usually, to pollution of the harbor waters and to consequent death and partial decay of the growths, exact determinations were not always possible, especially with hydroids, where one often found only empty "stems." For determination of the total amount of fouling present, known areas were scraped carefully and the material collected, measured, and weighed while wet; and in some cases the relative amounts of each of the fouling agencies were determined. In addition, the itinerary of each vessel was secured whenever possible, and the date of previous docking also was obtained. For the great majority of vessels examined the paint used was the "United States Navy standard" (used by the Shipping Board as well as the Navy), and notation was made of all exceptions. On the data thus obtained the following report is based.

However, in order to determine more accurately the validity of some of the theories that presented themselves during the course of this investigation, considerable experimental work was carried on simultaneously, and the results of these experiments also are included in their appropriate places.

NATURE OF FOULING

As previously stated, the fouling of ships' bottoms is caused by growths of both plants and animals. Among the workers at the dry docks one hears the terms "grass," "moss," and "corals" as describing the types of growths found on ships. It is quite evident that the term "grass" is commonly applied to the stems, or cœnosarcs, of hydroids, and that the term "moss" is applied to the various seaweeds, usually green algæ, which are found so commonly near the water line. The term "shells" includes all shelly growths, such as barnacles, oysters, clams, mussels, and even certain Bryozoa; but more commonly barnacles are recognized as distinct from the other "shells," while the corals so frequently mentioned are probably Byrozoa, for coral itself has been found rarely.

These groups of organisms, then—barnacles, algæ, hydroids, mullusks, Bryozoa, and tunicates—make up the preponderance of the growths that are found on the bottoms of ships. In the determination of the forms collected it has often been quite impossible to ascertain the exact species with finality. This was due to the fact that

many of the growths either were dead, and all their soft parts entirely gone, or they were but recently dead and in a putrid condition when the ship was docked and the collections made.

LIST OF THE SPECIES OF ORGANISMS COLLECTED FROM SHIPS' BOTTOMS

Animals:
- Phylum ARTHROPODA—
  - Class CIRRIPEDIA (barnacles)—
    - Balanus improvisus.
    - B. eburneus.
    - B. amphitrite.
    - B. tintinabulum.
    - B. crenatus.
    - B. harmeri.
    - B. tulipiformis.
    - B. perforatus.
    - Balanus sp.?
    - Chthamalus fragilis.
    - Lepas anatifera.
    - L. anserifera.
    - L. hillii.
    - Conchoderma aurita.
    - C. virgatum.
    - Pæcilasma crassa.
- Phylum MOLLUSCA—
  - Class PELECOPODA—
    - Mytilis edulis.
    - M. hamatus.
    - Mya sp.?
    - Ostrea elongata.
    - Anomea ephippium.
    - Anomea sp.?
  - Class GASTEROPODA—
    - Crepidula fornicata.
    - Nudibranchiata sp.?
- Phylum COELENTERATA—
  - Class HYDROZOA (hydroids)—
    - Eudendrium ramosum.
    - Eudendrium sp.?
    - Tubularia crocea.
    - T. couthouyi.
    - Tubularia sp.?
    - Campanularia amphora.
    - C. portium.
    - C. vorticellata.
    - Campanularia sp.?
    - Bougainvillia carolinensis.
    - Obelia commissuralis.
    - O. gelatinosa.
    - Obelia sp.?
    - Perigonimus jonsii.
    - Podocoryne sp.?
  - Class ANTHOZOA—
    - Metridium sp.?
    - Segartia luciæ.
    - Astrangia sp.?
- Phylum PROTOZOA—
  - Class INFUSORIA—
    - Vorticellidæ.
    - Folliculina sp. ?

Animals—Continued.
- Phylum BRYOZOA—
  - Class ECTOPROCTA—
    - Bugula turrita.
    - Bowerbankia caudata.
    - B. gracilis.
    - Anguinella palmeta.
    - Alcyonidium mytili.
    - A. gelatinosum.
    - Membranipora monostachys.
    - M. lacroixii.
    - M. liniata.
    - Membranipora sp.?
    - Lepralia pertusa.
    - Crissia sp.?
- Phylum ANNELIDA (worms)—
  - Class POLYCHÆTA—
    - Hydroides hexagonis.
    - Hydroides sp.?
    - Nereis pelagica.
    - Glycera sp.?
- Phylum CHORDATA—
  - Class TUNICATA (sea squirts)—
    - Molgula manhattensis.
    - M. arenata.
    - Botryllus arenata.
    - B. schlosseri.
    - B. nigrum.
    - Ciona intestinalis.

Plants:
- Division ALGA—
  - Class CYANOPHYCEÆ—
    - Oscillatoria lætevirens.
  - Class CHLOROPHYCEÆ—
    - Cladophora sp.?
    - Enteromorpha intestinalis.
    - E. torta.
    - E. chætomorphoides.
    - E. marginalis.
    - Enteromorpha sp.?
    - Ulothrix flaca.
    - Ulva lactuca.
    - Vaucheria sp.?
    - Acrochætium sp.?
  - Class PHÆOPHYCEÆ—
    - Ectocarpus sp.?
    - Fucus sp.?
  - Class RHODOPHYCEÆ—
    - Polysiphonia nigrescens.
    - P. violacea.
    - Polysiphonia sp.?

In the foregoing list are given the organisms collected from ships' bottoms and identified as far as the condition of the material would permit. By referring to this list it will be seen that 48 species of animals have been found, in addition to 13 types that could be classified only as to genera; while all of the plants found were algæ, of which 16 kinds were recognized.

As will be seen, the largest number of forms is found in the group of barnacles. (Figs. 2 and 3.) These organisms vary greatly in size and shape, many kinds never growing more than one-fourth inch in diameter, and often not so high. Some species, however, notably those that attach on ships in tropical waters, grow to a very considerable size—4 inches in diameter and 6 inches in height. Very frequently they are found growing one upon another, so that the height of a cluster occasionally may reach 8 or even 10 inches. Most barnacles are protected by means of hard calcareous plates, which surround the animal, forming a sort of shell. These plates vary in number, with the kind of barnacle, from four to very many; but the more common forms (Balanus) all have six plates or compartments forming the walls of the shell and two pairs of plates that comprise the top or covering of the shell, and which are arranged like valves. Between these valves the animal extends its thoracic appendages when feeding. (Fig. 4.) This peculiar habit has given rise to a popular description of a barnacle as an "animal which stands on its head and kicks its food into its mouth." Some barnacles, however, do not form heavy calcareous shells and are very much elongated. (Fig. 5.) These are commonly called "gooseneck" barnacles and include the last six species of barnacles listed on page 199. Since the "neck" or stalked portion of this type of barnacle is not protected by shelly structure, such growths fall off upon the death of the organism; but all other types of barnacles leave behind them their shells or houses, which frequently persist for many years if not forcibly removed.

Barnacles have a complicated life history. The eggs are fertilized within the body chamber of the adult and held in lamellar folds until the young are hatched. The almost microscopic larval organism is free-swimming, with three pairs of appendages and a single median eye, and is known as the "nauplius." (Fig. 6 *A*.) After a period varying from 1 to 10 days, or more, these nauplii metamorphose into tiny bivalved forms called the "cyprid" larvæ. (Figs. 6 *B*, *C*, and *D*.) At this time the larval barnacle has six pairs of appendages, like the adult, and two long antennæ with many sensitive hairs or bristles. The median eye is sometimes lost, and paired compound eyes are always present.

These young barnacles, resembling miniature clams, float and swim about for a considerable time, often for two or three months, and finally attach by use of apparently adhesive pads on the tips of the two antennæ. (Figs. 6 *B* and *C*.) After attachment, they metamorphose into the adult stage, miniature at first but growing rapidly to full size. At the time of this radical change the eyes apparently are lost in some forms. It is the study of these cyprid larvæ at the time of attachment, of course, which is of fundamental importance in an investigation of the fouling of ships' bottoms.

It is of interest to note that of the 150 species of barnacles listed by Charles Darwin in his monograph of 1853, only 15 kinds have been found on ships examined for this investigation, and that all of the commonest are typical shore forms, normally inhabiting shallow water (and rarely living at depths in excess of 10 fathoms), such forms as are found in most harbors and sheltered coastal areas.

The hydroids are the next most numerous animal group, with 15 types found during the investigation. Hydroids usually are colonial in their growth and have an even more complicated life history than do the barnacles. These growths begin

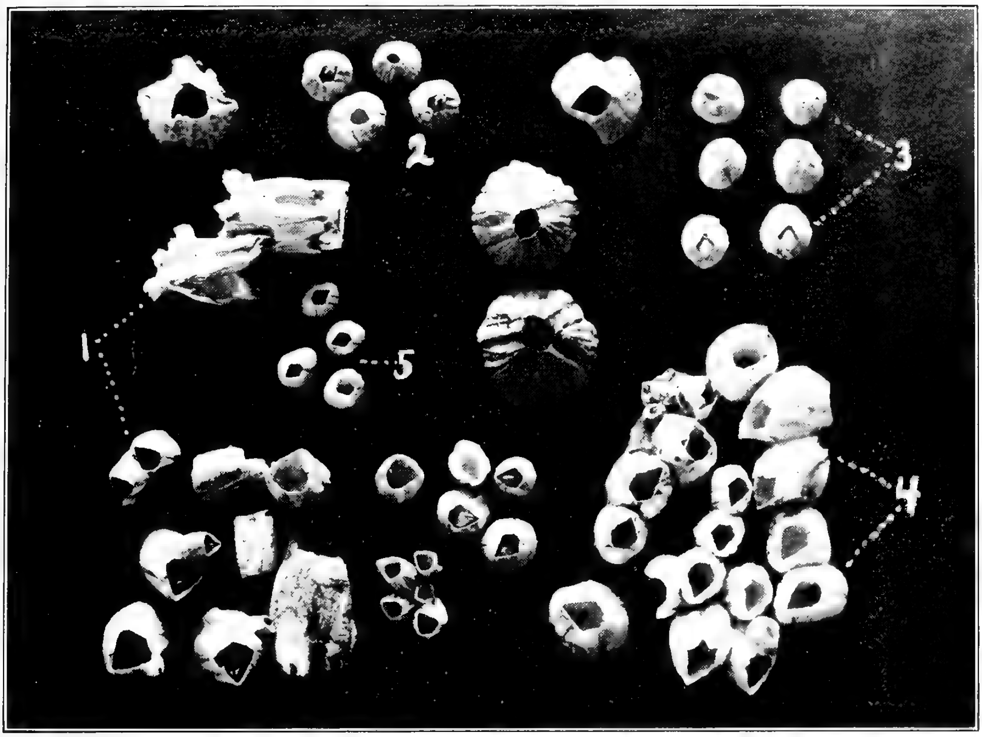


Fig. 2.—Sizes and shapes of sessile barnacles found on ships, bottoms. 1, *Balanus tintinabulum;* 2, *B. crenatus;* 3, *B. improvisus;* 4. *B. eberneus;* 5, *B. amphitrite*

Fig. 3.—Sizes and shapes of sessile barnacles found on ships' bottoms. A cluster of *B. tintinabulum*

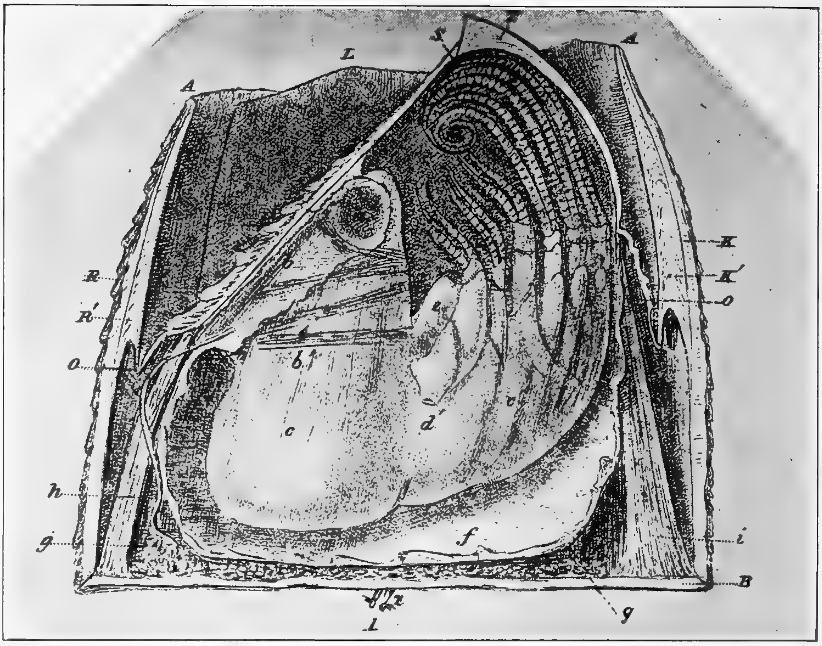


Fig. 4.—Internal structure of a typical sessile barnacle. (After Darwin)

Fig. 5.—Stalked barnacles collected from ships' bottoms. 1, Conchoderma; 2, Lepas

after attachment of a free-swimming larva, which changes its form completely upon fixation and produces a stalked growth or stolon. In many forms this stalk branches profusely and forms a treelike structure, often attaining a length of 6 or 8 inches. (Fig. 7.) Here, too, the living animal is inclosed within a chitinous sheath, which

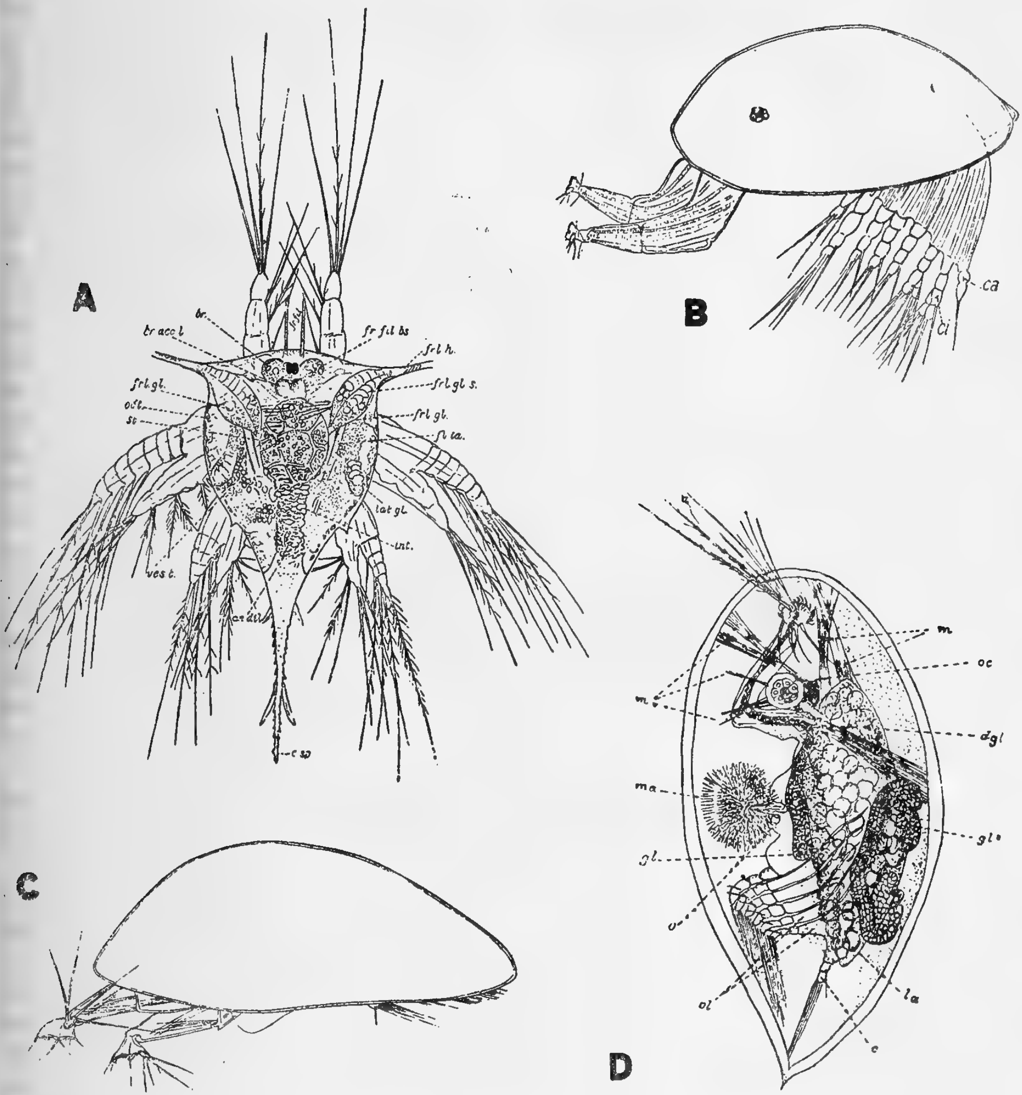


FIG. 6.—Larval stages in the development of barnacles and the condition of the antennæ at the time of attachment. *A*, dorsal view of the nauplian larva of *Balanus perforatus* (after Groom); *B*, cyprid larva of *Tetraclita divisa* (after Nilsson Cantell); *C*, cyprid larva of Scapellum (after Nilsson Cantell); *D*, lateral view of a cyprid of *Lepas fasiculatus*, showing internal anatomy (after Willemoes, as in Hoek)

persists (especially in the case of Tubularia) for many months after the death of the organism. Since these colonial organisms obtain their food by means of feeding polyps, which are situated at the ends of the stalk or its branches, and since all other parts of their bodies are protected by the chitinous *hydrotheca*, it is apparent

that after attachment, in the case of these organisms as well as of the barnacle, they are completely resistant to any ingredients of a paint film. The problem of prevention of fouling accordingly resolves itself into one of prevention of attachment of these forms.

Bryozoa are a group of organisms abundantly present on all marine coasts but much less abundant now than in prehistoric times. The great majority of them form colonies of thousands of relatively small individuals, each of which is surrounded by a more or less chitinous or calcareous shell. They may be either aborescent in their form of growth, as Bugula (fig. 8 *A*), or more commonly they form an encrusting lamellar growth, as in the case of Membranipora. (Figs. 8 *B* and *C*.) These growths frequently vary greatly in their form and may produce "sea mats" and coraline structures, which may form growths 6 to 8 inches in height and 12 inches in diameter. Each colony originates from a single minute larva, which has a free-swimming period persisting from one to many hours.

In the case of mollusks, such forms as oysters and anomia attach directly to the surface of the vessel and may grow to considerable size. Thus, oysters have been collected fully 5 inches in length and 3 inches in width. (Fig. 9.) Such forms as Mytilis, on the other hand, attach by means of byssal threads, and although they grow to a very considerable size (fig. 9), upon the death of the organisms the shell drops off, although the byssal threads may still persist for many years, leaving a telltale story of their former presence. These forms, also, at the time they attach, are minute, free-swimming larvæ, which in several cases are known to be sensitive to light.

Of the annelids, only one type occurs at all abundantly, this being the serpulids, which form calcareous, tube-shaped shells. (Fig. 10 *B*.) Hydroides tubes have been found fully 3 inches long, and on a few ships in large numbers. This is the only type of this group that has been found attaching directly to the hull, the other forms listed being only casual inhabitants of the rich growths, both faunal and floral, that are found on some ships.

The Protozoa, unicellular forms, are indicative of the environment in which the ship has been. The Vorticellidæ, in particular, indicate a putrid environment and on some ships were very abundant.

The tunicates, or sea squirts, are both solitary and colonial in type. The former were found more often and frequently grew to large size. (Fig. 10 *A*.) The colonial forms are incrusting types and do not produce as large an amount of growth as the other forms. These, too, are free-swimming organisms at the time of attachment.

The algæ were the most ever-present form, with the possible exception of the barnacles. They frequently formed heavy mats of growth, extending from the water line to from 1 to 8 feet below. Although individual growths might be of little consequence, the large numbers frequently made the mass appear much like a beautiful lawn. In many cases the growths of algæ, especially the Enteromorpha, would attain a length of 7 to 10 inches. It is interesting to note that both the Enteromorpha and Cladophora are remarkable for the fact that many of their species are found indifferently in both salt and fresh water, and that they are characteristic plants of the littoral zone, rarely, if ever, extending into the sublittoral.

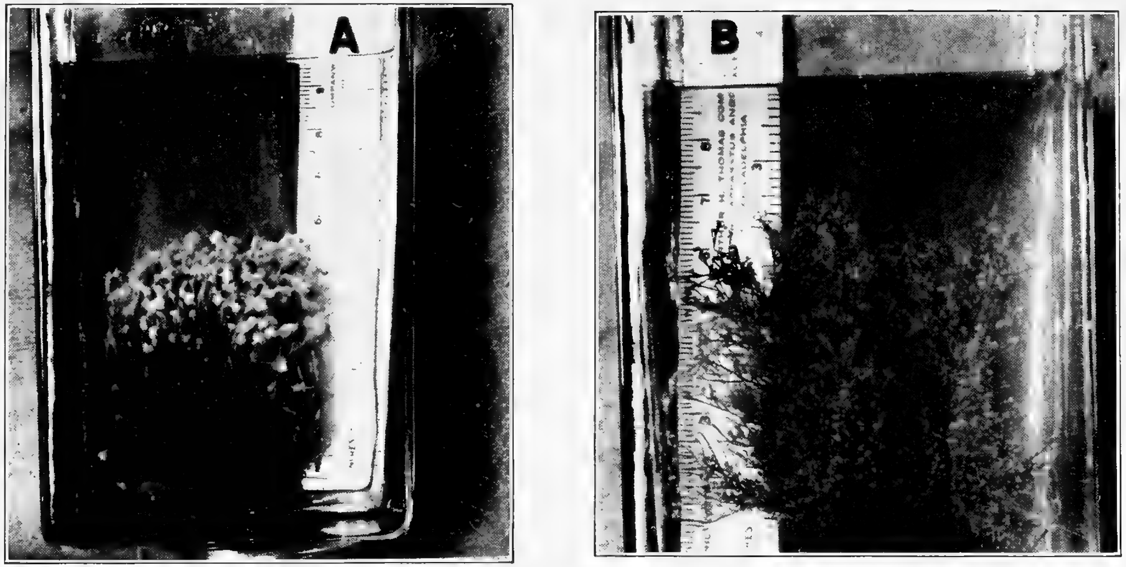
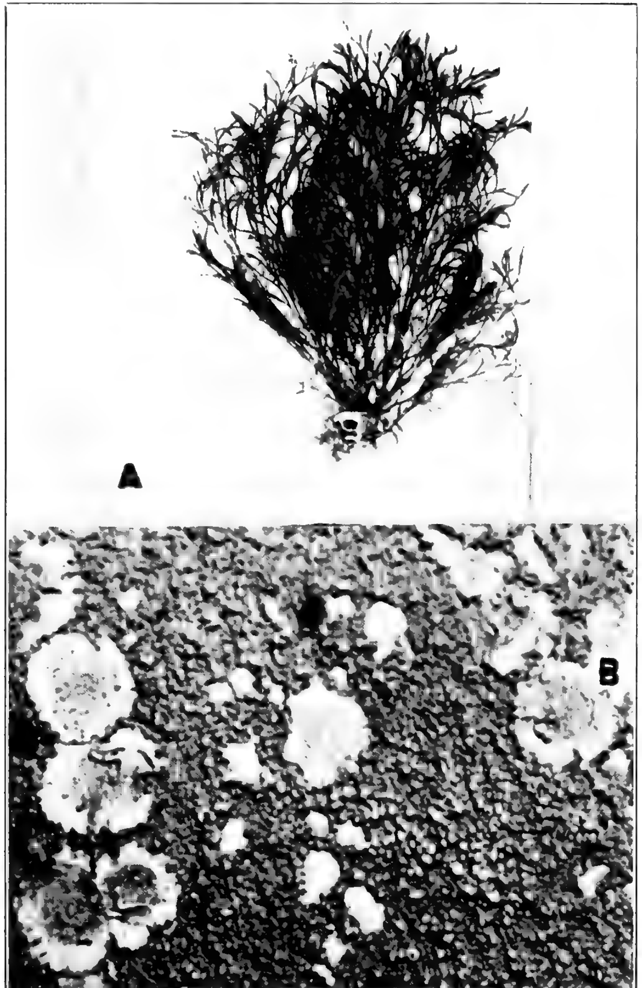


Fig. 7.—Types of hydroids found on ships' bottoms, collected from the U. S. S. *Florida*. A, a cluster of Tubularia; B, a cluster of Eudendrium



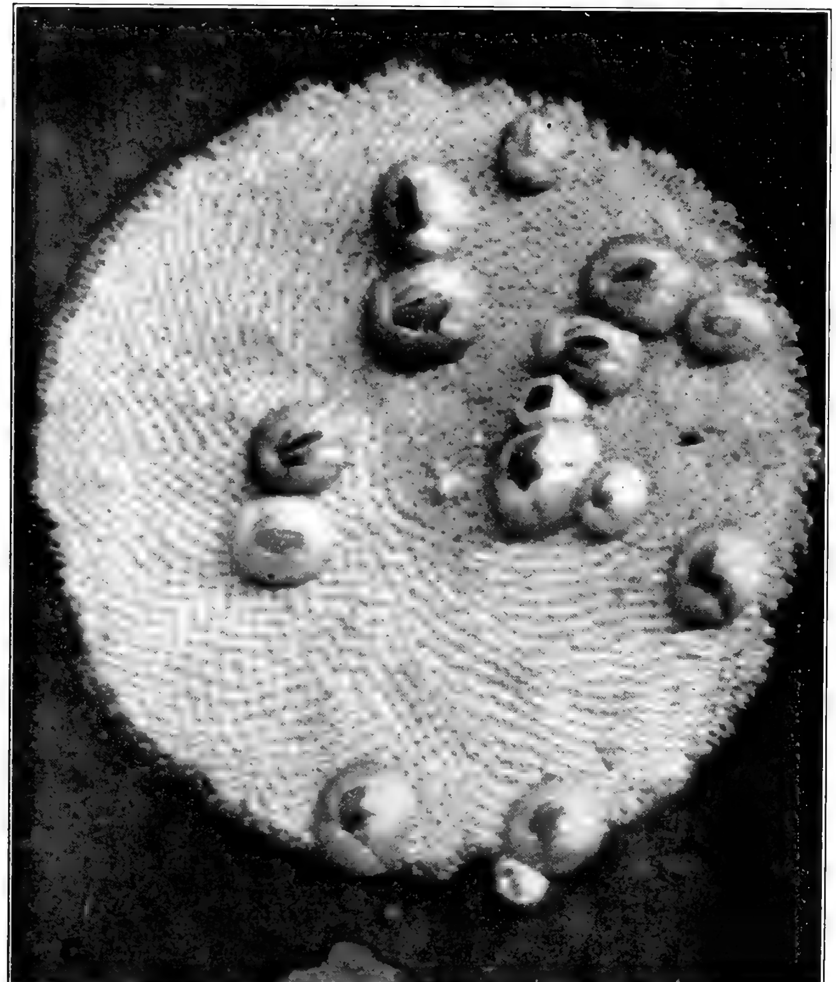


Fig. 8.—Types of Bryozoa (Polyzoa) that cause fouling on ships' bottoms. A, colony of Bugula; B, several colonies of Membranipora from 4 to 6 inches in diameter; C, colony of Membranipora photographed on the hull of the U. S. S. *Texas*, showing *Balanus improvisus* growing upon it

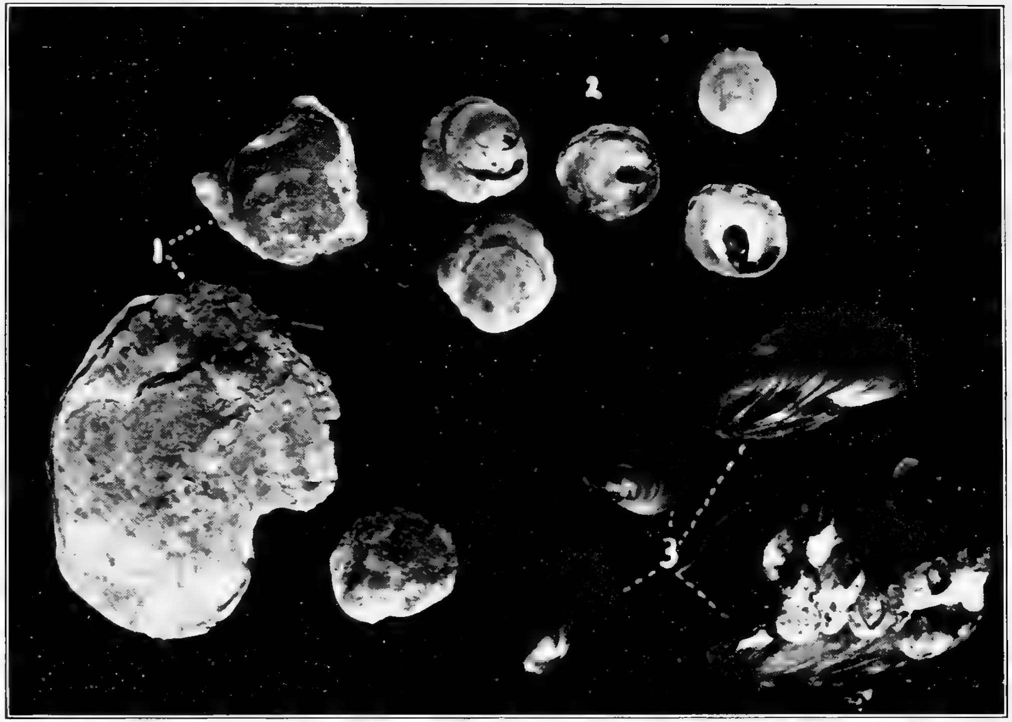


FIG. 9—Types of mollusks found as fouling on ships' bottoms. 1, Ostrea; 2, Anomia; 3, Mytilus

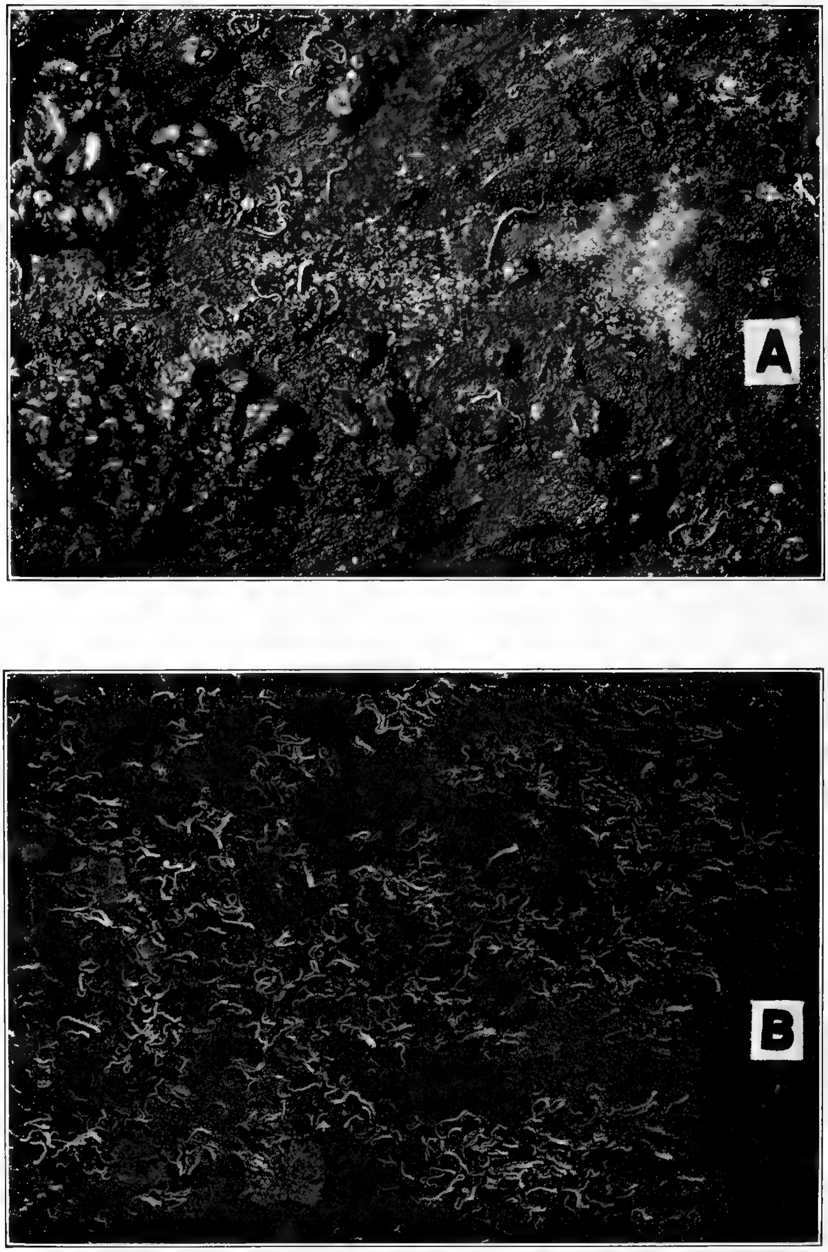


FIG. 10.—Types of fouling. **A,** clusters of the tunicate (sea squirt) Ascidia. **B,** numerous specimens of the serpulid worm Hydroides, showing the calcareous tubes in which they dwell

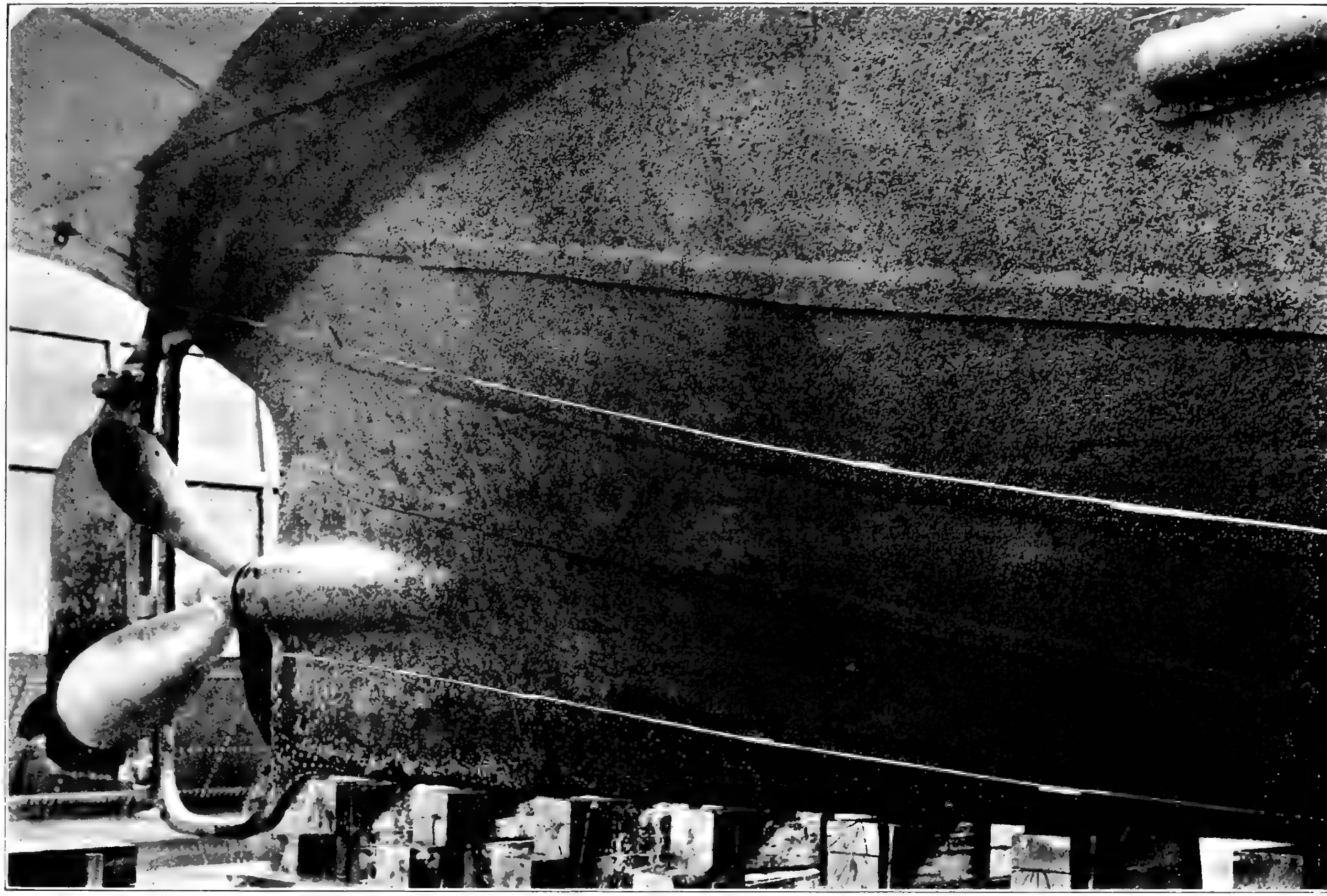


Fig. 11.—Relative amounts of fouling on ships. U. S. S. *Owl* lightly fouled

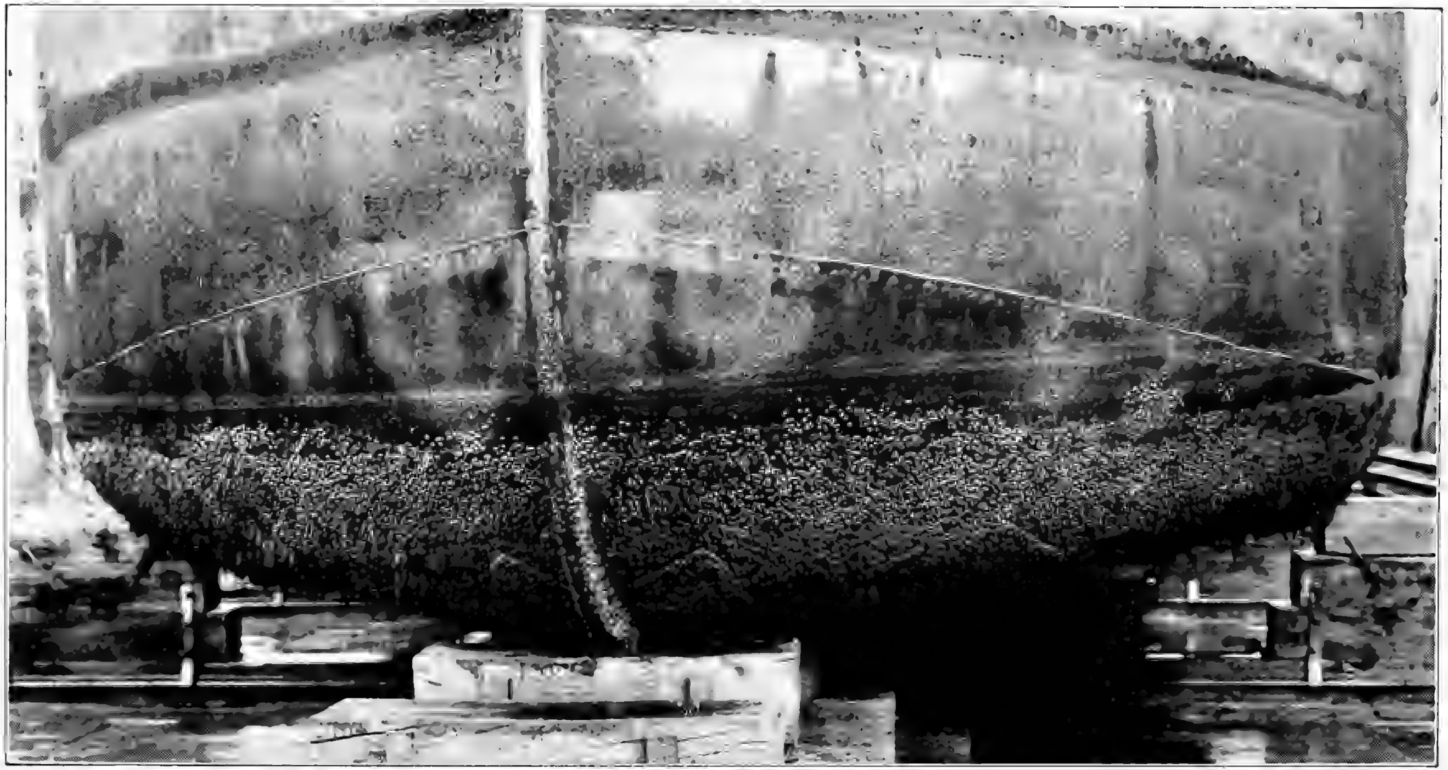


FIG. 12.—Relative amounts of fouling on ships. A barge at the Norfolk Navy Yard moderately fouled

FIG. 13.—Relative amounts of fouling on ships. U. S. S. *Chester* heavily fouled

Fig. 14.—Amount and type of fouling. 1. Balanus; 2, Bryozoa; 3, Hydroides

Fig. 15.—Amount and type of fouling. Heavy accumulation of hydroids, tunicates, and barnacles on propeller and struts

EXTENT OF FOULING

The prevalence and amount of fouling is surprising to anyone who witnesses for the first time the docking of marine vessels. In earlier times it was not uncommon for ships to have their entire bottoms incrusted with organisms to a depth varying from 5 to 9 inches, with estimated weights of 300 tons or more. In recent years, due especially to more regular and frequent dry docking, such conditions are experienced but rarely; but even to-day, after vessels have been at sea for 6 or 8 months, they frequently accumulate growths from 2 to 3 inches in depth, and vessels with from 50 to 100 tons of fouling are seen frequently. When one realizes that all ships become foul if submitted to the usual environment, the extent and prevalence of fouling can be realized. In Figures 11, 12, and 13 are shown conditions typical of lightly, moderately, and heavily fouled ships, while in Figures 14 to 19 are seen the kinds of growths contributing to these conditions.

In Table 1 is given a list of all of the vessels examined during this investigation, with notations regarding the amount of fouling on each. By reference to this table it can be seen that there is great variation in the amount of fouling on various ships. The reasons for this will be discussed under separate headings in another section of this paper dealing with the factors that determine fouling.

TABLE 1

Ship	Type	Date examined	Period out of dock (in months)			Waters cruised	Degree of fouling				Predominating type of fouling organism
			Total time	Time cruising	Time in port		Heavy	Moderate	Light	None	
Proteus	Collier	Sept. 28, 1922	11.0	2.0	9.0	Norfolk-Cuban waters	×				Barnacles, hydroids.
Maryland	Battleship	Oct. 12, 1922	2.3	2.0	.3	New York-Brazil			×		Algæ, barnacles.
Fish Hawk	U. S. B. F. vessel	Nov. 7, 1922	17.0	5.0	12.0	New York-Chesapeake		×			Hydroids.
West Virginia	Battleship	Nov. 21, 1922	12.0		12.0	Newport News, Va.	×				Barnacles, hydroids.
Parker	Destroyer	Nov. 23, 1922	21.0	1.0	20.0	Charleston, S. C.-Philadelphia, Pa.		×			Barnacles, mussels.
O'Brien	do	do	21.0	1.0	20.0	do		×			Oysters, barnacles.
Rail	Mine sweeper	Nov. 28, 1922	11.0	5.0	6.0	Cuban waters-Philadelphia, Pa.	×				Algæ, Bryozoa.
Bobolink	do	do	19.0	9.0	10.0	do	×				Do.
Rochester	Cruiser	Dec. 5, 1922	14.0	4.0	10.0	Charleston, S. C.-Philadelphia, Pa.		×			Barnacles, hydroids.
Washington	Battleship	Dec. 11, 1922	12.0		12.0	Philadelphia, Pa.			×		Algæ.
Wright	Aircraft tender	do	13.0	3.0	10.0	Cuba-Chesapeake-New York		×			Barnacles, hydroids.
Wyoming	Battleship	Dec. 17, 1922	6.0	2.0	4.0	Chesapeake-Cuba-New York	×				Do.
Nevada	do	Jan. 5, 1923	5.0	2.0	3.0	New York-Brazil		×			Barnacles.
Kittery	Cargo ship	Jan. 22, 1923	8.0	5.0	3.0	Cuba-Chesapeake-New York			×		Algæ, barnacles.
Beale	Destroyer	Feb. 2, 1923	46.0	2.0	44.0	Philadelphia Navy Yard			×		Barnacles, hydroids.
Warrington	do	do	43.0		43.0	do			×		Do.
Henderson	Transport	Feb. 12, 1923	9.0	6.0	3.0	Japanese-Cuban via Panama Canal		×			Algæ.
Antares	Auxiliary	do	7.0	1.0	6.0	Chesapeake-New York-Philadelphia	×				Barnacles, hydroids.
America	Passenger	Feb. 24, 1923	7.0	7.0		Transatlantic			×		Algæ.
Eagle 44	Eagle boat	do	(?)	(?)	(?)	North River, New York, Ninety-sixth Street		×			Barnacles.
Eagle 48	do	do	(?)	(?)	(?)	Perth Amboy, N. J.		×			Do.
Eagle 51	do	do	(?)	(?)	(?)	North River, New York, Ninety-sixth Street		×			Do.
American Legion	Passenger	Mar. 15, 1923	7.0	7.0		New York-Rio de Janeiro				×	
Denver	Cruiser	do	7.5	7.0	.5	New York-Cuba-Panama			×		Barnacles, hydroids.
Florida	Battleship	do	15.5	4.0	11.5	Boston-New York-Cuba	×				Hydroids.
President Monroe	Passenger	Mar. 22, 1923	6.0	6.0		(?)				×	
S. C. 103	Submarine chaser	do	21.0	3.0	18.0	New Haven, Conn.		×			Barnacles.
S. C. 271	do	do	21.0	3.0	18.0	do		×			Barnacles, Bryozoa,
S. C. 143	do	do	24.0	4.0	20.0	North River, New York, Twenty-third Street	×				Barnacles.
Privateer	Naval yacht	do	6.0		6.0	New York Navy Yard				×	
Traffic	Naval tug	do	24.0	12.0	12.0	do				×	
East Wind	Freighter	Apr. 2, 1923	8.0	8.0		Australia-New York			×		Algæ.
Arkansas	Battleship	do	16.0	8.0	8.0	Cuban waters-New York	×				Barnacles.
Argonne	Transport	Apr. 5, 1923	11.0	7.0	4.0	California-Philadelphia via Panama Canal			×		Algæ.
Williamson	Destroyer	do	(?)	(?)	(?)	(?)			×		Barnacles, Bryozoa.
Orion	Collier	do	12.0	7.0	5.0	Chesapeake-Cuban		×			Do.
Cleveland	Cruiser	do	(?)	(?)	(?)	(?)	×				Do.
Eagle 54	Eagle boat	Apr. 14, 1923	(?)	(?)	(?)	North River, New York, Two hundred and twelfth Street.		×			Barnacles, hydroids.
Eagle 15	do	do	(?)	(?)	(?)	New London, Conn.		×			Barnacles, Bryozoa.
Ossining	Freighter	do	11.0	10.0	1.0	New York-East coast South America			×		Algæ.
Natirar	do	do	5.5	5.5		New York-North Sea				×	
Maryland	Battleship	Apr. 16, 1923	7.0	2.0	5.0	Chesapeake-Cuban-New York		×			Do.
Reuben James	Destroyer	do	10.5	8.5	2.0	English-Chesapeake-New York		×			Algæ, barnacles.
Camden	Cruiser	Apr. 30, 1923	5.5	2.5	3.0	Seattle-New York via Panama Canal	×				Barnacles, algæ.
Independence	Freighter	do	7.5	5.5	2.0	Round the world via both canals		×			Algæ, barnacles.
St. Paul	Passenger	May 16, 1923	(?)	(?)	(?)	New York Harbor		×			Algæ.
William Penn	Freighter	May 15, 1923	7.0	6.0	1.0	Japanese-Philadelphia via Panama Canal		×			Barnacles.
Leviathan	Passenger	May 18, 1923	50.0		50.0	Newport News and New York	×				Do.
Half Moon	Freighter	May 23, 1923	6.0	5.5	.5	East Indies, via Suez		×			Do.
Surinam	do	June 11, 1923	9.0	9.0		New York-South America				×	
Paul Luckenbach	do	do	12.0	11.5	.5	New York-Portland, via Panama Canal		×			Do.

Azalea	Lightship tender	June 13, 1923	8.0	(?)	(?)	New England waters			×		Algæ, barnacles.
Sinsinawa	Freighter	June 18, 1923	9.0	8.5	.5	New York–Mediterranean			×		Algæ.
Scottsburg	do	June 23, 1923	.7	.5	.2	Pier 38, Brooklyn			×		Cyprids.
Pan America	Passenger	July 14, 1923	2.5	2.5		New York–South America			×		Young barnacles.
Chester	Cruiser	July 25, 1923	30.0		30.0	Boston Navy Yard	×				Mussels, hydroids.
Tacoma	do	do	8.5	8.0	.5	New York–Canal Zone		×			Barnacles, algæ.
Edgemont	Freighter	July 26, 1923	25.0		25.0	Staten Island Sound	×				Do.
Majestic	Passenger	Aug. 4, 1923	9.0	9.0		Transatlantic			×		Algæ, barnacles.
Phalarope	U. S. B. F. vessel	Aug. 14, 1923	12.0	2.0	10.0	Chesapeake–New England			×		Bryozoa, barnacles.
E. A. Morse	Freighter	Aug. 22, 1923	24.0		24.0	New London, Conn	×				Mussels, barnacles.
Nobles	do	do	13.0		13.0	Pier 5, Staten Island	×				Hydroids, barnacles.
Edenton	do	Sept. 11, 1923	24.0		24.0	New Haven, Conn	×				Barnacles, mussels.
Chinook	Dredge	Sept. 20, 1923	18.0	(?)	(?)	Hampton Roads	×				Barnacles, hydroids.
McFarland	Destroyer	do	1.0	1.0		New York–Boston			×		Algæ.
West Nohno	Freighter	Nov. 20, 1923	6.0	6.0		Azores, west coast of Africa	×				Large Barnacles.
Saint Mihiel	Army transport	do	7.5	(?)	(?)	Canal Zone–Hampton Roads		×			Barnacles, algæ.
Goff	Destroyer	Nov. 21, 1923	9.0	7.0	2.0	Constantinople–Norfolk			×		Algæ, barnacles.
Gilmer	do	do	5.0	4.0	1.0	do			×		Do.
S-11	Submarine	do	4.0	1.0	3.0	New England waters		×			Do.
Sands	Destroyer	do	14.0	8.0	6.0	Constantinople–Norfolk			×		Do.
Childs	do	do	(?)	(?)	(?)	Chesapeake			×		Do.
Surinam	Freighter	Nov. 24, 1923	6.0	6.0		Caribbean			×		Barnacles, Bryozoa.
Commack	do	Nov. 27, 1923	8.0	8.0		New York–Argentina			×		Barnacles, algæ.
Reuben James	Destroyer	Nov. 28, 1923	8.0	(?)	(?)	Constantinople			×		Do.
Ourcq	Army transport	Nov. 30, 1923	(?)		(?)	James River, Va	×				Oysters, mussels.
Eastern Leader	Freighter	Dec. 5, 1923	1.0	1.0		Transatlantic				×	
Hopkins	Destroyer	Dec. 7, 1923	9.0	7.0	2.0	Constantinople–Norfolk			×		Algæ, hydroids.
Kane	do	do	9.0	7.0	2.0	do			×		Do.
S-10	Submarine	do	7.0	5.0	2.0	New England coast		×			Do.
Cantigne	Army transport	Dec. 12, 1923	10.5		10.5	James River, Va	×				Mussels.
Independence	Freighter	Dec. 10, 1923	7.5	7.5		Around world via Suez			×		Barnacles, hydroids.
America	Passenger	Dec. 19, 1923	10.0	9.5	.5	Transatlantic			×		Algæ.
Wright	Aircraft tender	Dec. 23, 1923	12.0	6.5	5.5	Canal, Chesapeake–New York	×				Barnacles, algæ.
West Irmo	Freighter	Jan. 7, 1924	7.0	7.0		Caribbean			×		Barnacles.
Angelus	do	do	27.0		27.0	Pauls Island, N. Y	×				Barnacles, hydroids.
Waban	do	do	22.0		22.0	do		×			Do.
William Penn	do	Jan. 9, 1924	7.5	7.0	.5	Around world via Suez			×		Barnacles.
Bird City	do	Jan. 19, 1924	12.5	12.0	.5	New York–East coast of South America			×		Do.
Western Plains	do	Jan. 22, 1924	11.0		11.0	Staten Island Sound		×			Algæ, barnacles.
West Virginia	Battleship	Jan. 27, 1924	16.0	1.0	15.0	Newport News, Va		×			Do.
West Nestleton	Freighter	Feb. 7, 1924	3.0	3.0		West coast of Africa		×			Barnacles, hydroids.
Tulsagas	Tanker	Feb. 13, 1924	4.5	4.5		New York–Canal Zone			×		Barnacles, algæ.
President Garfield	Passenger	Feb. 14, 1924	9.0	9.0		Transatlantic				×	
Argosy	Freighter	Feb. 14, 1924	3.5	3.0	.5	New York–West coast of South America			×		Algæ.
Rapidan	Auxiliary	Feb. 20, 1924	20.0	1.0	19.0	Norfolk–New York	×				Barnacles, oysters.
Chaumont	Army transport	Feb. 23, 1924	10.0	10.0		New York–Seattle, via Panama Canal			×		Algæ, barnacles.
Eastern Tempest	Freighter	do	5.5	5.5		New York–North Sea				×	
Volunteer	do	Feb. 25, 1924	11.5	11.0	.5	New York–China, via Panama Canal			×		Barnacles.
Easterner	do	Feb. 29, 1924	6.0	5.0	1.0	New York–Australia, via Panama Canal			×		Algæ.
Leviathan	do	Mar. 1, 1924	9.0	7.0	2.0	Transatlantic			×		Algæ, barnacles.
West Loquassuck	do	Mar. 7, 1924	6.0	6.0		New York–West coast of Africa			×		Barnacles, Bryozoa.
Western World	do	Mar. 8, 1924	5.5	5.5		New York–South America				×	
Endicott	do	Mar. 15, 1924	7.5	7.5		Around world, via Suez-Panama Canals				×	
Clontarf	do	do	5.5	5.5		New York–Black Sea			×		Barnacles, algæ.
Rochester	Cruiser	Mar. 20, 1924	9.0	9.0		New York–Central America		×			Barnacles, Bryozoa.
Eastern Pilot	Freighter	Mar. 24, 1924	7.0	7.0		New York–Bristol			×		Algæ.
Raleigh	Cruiser	Mar. 25, 1924	3.0		3.0	Newport–Boston				×	
Texas	Battleship	Mar. 26, 1924	5.0	5.0		California–New York, via Panama Canal		×			Algæ, barnacles.
New York	do	Apr. 3, 1924	7.0	6.0	1.0	do		×			Algæ, hydroids.
Stanley	Freighter	Apr. 4, 1924	6.0	6.0		New York–Philippines, via Panama Canal			×		Barnacles, Bryozoa.
Wyoming	Battleship	Apr. 8, 1924	7.0	5.0	2.0	Boston–Canal Zone			×		Barnacles.
Litchfield	Destroyer	Apr. 10, 1924	6.0	1.0	5.0	Mediterranean–New York				×	(Moravian paint.)
Fox	do	do	12.0	3.5	8.5	Mediterranean, Chesapeake–New York			×		Barnacles.
Zarembo	Freighter	Apr. 11, 1924	9.0	9.0		New York–Bordeaux			×		Algæ.

TABLE 1—Continued

Ship	Type	Date examined	Period out of dock (in months)			Waters cruised	Degree of fouling				Predominating type of fouling organism
			Total time	Time cruising	Time in port		Heavy	Moderate	Light	None	
Eastern Sword	Freighter	Apr. 11, 1924	5.5	5.5		New York–Bristol				×	
Nile	do	Apr. 16, 1924	5.5	5.5		New York–East Indies, via Panama Canal			×		Algæ.
Hog Island	do	do	3.5	3.5		New York–Mediterranean		×			Algæ, barnacles.
Pan America	Passenger	Apr. 17, 1924	9.0	9.0		New York–East coast of South America			×		Barnacles.
Haiti	Freighter	Apr. 18, 1924	8.5	8.5		New York–West Indies			×		Algæ, barnacles.
Majestic	Passenger	do	9.5	(?)	(?)	Transatlantic			×		Algæ.
Eastern Glade	Freighter	Apr. 19, 1924	11.0	11.0		Southeast coast of Africa		×			Barnacles.
Sirius	Cargo ship	do	8.5	7.0	1.5	West and east coasts of United States, via Panama Canal.			×		Algæ, hydroids.
King	Destroyer	do	(?)	(?)	(?)	(?)			×		Do.
Arkansas	Battleship	Apr. 22, 1924	4.0	2.0	2.0	New York, Chesapeake–Panama Canal		×			Barnacles.
Relief	Lightship tender	Apr. 26, 1924	12.0	1.0	11.0	New York Harbor	×				Barnacles, hydroids.
West Africa	Freighter	do	6.0	6.0		West coast of Africa	×				Do.
Homestead	do	do	5.5	5.5		New York–India, via Suez			×		Algæ.
West Gotomska	do	do	15.0		15.0	Staten Island Sound	×				Barnacles, hydroids.
Eastern Shore	do	May 2, 1924	33.0		33.0	do	×				Do.
Blue Triangle	do	do	(?)	(?)	(?)	Intercoastal United States ports			×		Algæ.
West Selene	do	May 14, 1924	11.0		11.0	Staten Island Sound		×			Barnacles.
Ballcamp	Tugboat	do	13.0	1.0	12.0	Caldwell, N. Y		×			Barnacles, hydroids.
Trenton	Cruiser	May 26, 1924	6.0	6.0		Newport–New York				×	
Half Moon	Freighter	do	6.0	5.0	1.0	New York–East Indies, via Suez		×			Barnacles, algæ
Chewink	Mine sweeper	June 2, 1924	15.5	1.5	14.0	New York–Canal Zone			×		Barnacles.
Northend	Lightship	do	10.5	.5	10.0	New York waters	×				Mussels.
Cincinnati	Cruiser	June 3, 1924	3.5	3.0	.5	Seattle–Chili–New York		×			Barnacles.
Western Glen	Freighter	June 4, 1924	4.0	4.0		Southeast coast of Africa			×		Algæ.
Pine	Lightship tender	June 11, 1924	11.5	1.0	10.5	Off Atlantic City		×			Barnacles, hydroids.
Colorado	Cruiser	June 12, 1924	3.0		3.0	New York Navy Yard				×	
West Cawthon	Freighter	June 14, 1924	9.5	9.5		New York–Mediterranean			×		Hydroids, Lepas.
Acme	do	do	7.0	7.0		New York–Mexico–Canal Zone			×		Algæ, barnacles.
Fire Island	Lightship	June 16, 1924	7.0		7.0	Fire Island, N. Y		×			Mussels, hydroids.
District of Columbia	Tanker	June 17, 1924	4.5	4.5		New York–California, via Panama Canal				×	
Kerhonkson	Freighter	June 18, 1924	7.0	7.0		New York–Ireland			×		Algæ.
West Calumb	do	June 23, 1924	6.0	6.0		New York–East Indies, via Suez			×		Algæ, Conchoderma.
West Irmo	do	June 28, 1924	5.5	5.5		New York–West coast of Africa		×			Barnacles, hydroids.
Eastern Tempest	do	June 30, 1924	4.0	4.0		New York–North Sea			×		Algæ.
Dochet	do	July 1, 1924	2.5	2.5		New York–Mediterranean			×		Algæ, barnacles.
Eastern Moon	do	July 2, 1924	5.0	4.5	.5	New York–Australia, via Panama Canal		×			Do.
Jennie R. Morse	do	July 7, 1924	6.0	6.0		New York–Japan, via Panama Canal		×			Do.
S-27	Submarine	do	7.0	1.0	6.0	New York–Boston–Cuba		×			Do.
Sagamore	Mine sweeper	July 8, 1924	1.3		1.3	New York Navy Yard			×		Minute barnacles.
Independence	Freighter	July 9, 1924	7.0	6.0	1.0	Around world, via Suez and Panama Canals		×			Algæ, barnacles.
Eastern Guide	do	July 11, 1924	6.5	6.0	.5	Transatlantic				×	
Henderson	Transport	do	9.0	5.0	4.0	Philadelphia–Canal Zone–East Indies			×		Minute barnacles.
Sturtevant	Destroyer	July 12, 1924	10.0	6.5	3.5	New York–New England–Cuban	×				Barnacles.
West Maximus	Freighter	July 14, 1924	3.5	3.5		New York–North Sea				×	
S-1	Submarine	do	12.0	.5	11.5	New London–New York–Chesapeake			×		Bryozoa, barnacles.
Southern Cross	Passenger	July 16, 1924	2.0	2.0		New York–Rio de Janiero				×	
Concord	Cruiser	July 25, 1924	3.0		3.0	New York Navy Yard		×			Barnacles.
Eastern Planet	Freighter	July 28, 1924	6.0	4.5	1.5	New York–Australia, via Panama Canal			×		Algæ, barnacles.
West Mahomet	do	July 30, 1924	6.5	6.0	.5	New York–East Indies, via Suez			×		Algæ.
Hampton Roads	do	Aug. 1, 1924	3.5	3.5		New York–San Pedro, via Panama Canal			×		Algæ, barnacles.
Sagamore	do	Aug. 5, 1924	7.5	5.5	2.0	New York–Mediterranean		×			Barnacles, algæ.

Scottsburg	do	do	7.0	5.5	1.5	New York-China, via Panama Canal		×			Barnacles.
America	Passenger	Aug. 8, 1924	8.0	8.0		New York-Cherbourg			×		Algæ.
West Hesseltine	Freighter	Aug. 12, 1924	6.0	5.0	1.0	New York-West coast of Africa		×			Barnacles, hydroids.
Overfalls	Lightship	Aug. 22, 1924	(?)	(?)	(?)	New York Harbor	×				Do.
Iuka	Tug	Aug. 19, 1924	(?)	(?)	(?)	New York		×			Barnacles.
West Kedron	Freighter	Sept. 2, 1924	6.0	6.0		New York-Northern South America				×	Algæ.
Cincinnati	Cruiser	Sept. 3, 1924	3.0		3.0	New York Navy Yard		×			Molgula.
Bengula	Freighter	Sept. 4, 1924	5.0	4.0	1.0	New York-West coast of Africa	×				Barnacles, hydroids.
Henley	Destroyer	Sept. 6, 1924	26.0		26.0	New York-Philadelphia				×	Minute barnacles.
Sabotawan	Freighter	Sept. 10, 1924	3.5	3.0	.5	New York-Mediterranean		×			Serpulids.
Childs	Destroyer	do	9.0	3.0	6.0	New York-Central America		×			Barnacles, algæ.
Humphreys	do	Sept. 17, 1924	10.0	3.0	7.0	do		×			Barnacles, tunicates.
Relief No. 16	Lightship	Sept. 27, 1924	9.0	(?)	(?)	New York-Cornfield Point	×				Tunicates, hydroids.
Cathlamet	Freighter	Sept. 29, 1924	6.0	5.0	1.0	New York-West coast of Africa	×				Barnacles, Bryozoa.
Marblehead	Cruiser	Oct. 4, 1924				New York-Philadelphia				×	
Coeur d'Alene	Freighter	Oct. 6, 1924	9.0	5.5	4.5	New York-Mediterranean	×				Barnacles, tunicates.
Teal	Mine sweeper	Oct. 15, 1924	10.0	3.0	7.0	New York-Central America	×				Tunicates, hydroids.
Sands	Destroyer	Oct. 20, 1924	11.0	3.0	8.0	do	×				Tunicates, barnacles.
Western Plains	Freighter	Oct. 22, 1924	5.0	2.0	3.0	New York-Baltic ports		×			Barnacles, hydroids.
Wright	Aircraft tender	Oct. 23, 1924	11.0	4.0	7.0	New York-Central America	×				Barnacles, tunicates.
Falcon	Mine sweeper	Oct. 27, 1924	15.0	7.0	8.0	New York-New England-West Indies		×			Barnacles, oysters.
Pentucket	Tug	Oct. 29, 1924	16.0	16.0		New York Navy Yard and adjacent waters			×		Do.
West Nohno	Freighter	Nov. 6, 1924	6.0	5.5	.5	New York-West coast of Africa	×				Do.
S-29	Submarine	Nov. 15, 1924	4.0	2.0	2.0	New York-New England		×			Barnacles.
Richmond	Cruiser	Nov. 17, 1924	12.0	6.0	6.0	New York-Ireland	×				Molgula.
Relief No. 78	Lightship	Nov. 18, 1924	(?)		(?)	New York-Block Island		×			Hydroids, barnacles.
Hopkins	Destroyer	Nov. 19, 1924	11.5	7.5	4.0	New York-Central America			×		Do.
Sturtevant	do	Nov. 20, 1924	3.0	2.0	1.0	New York-Cuban			×		Barnacles.
Barry	do	Nov. 26, 1924	4.5	1.5	3.0	New York-Labrador			×		Do.
Gilmer	do	Dec. 3, 1924	3.0	1.5	1.5	New York-Norfolk-West Indies			×		Do.
Illinois	Battleship	Dec. 4, 1924	26.0	1.0	25.0	New York Harbor	×				Molgula, barnacles.
Wytheville	Freighter	do	4.5	3.5	1.0	New York-South Africa			×		Minute barnacles.
Hanley	do	Dec. 9, 1924	3.0		3.0	New York-Philadelphia				×	
West Humhaw	do	Dec. 10, 1924	6.0	5.5	.5	New York-West coast of Africa		×			Barnacles.
Beale	Destroyer	Dec. 16, 1924	5.0	3.0	2.0	New York-Philadelphia-Block Island			×		Bryozoa.
Pollock	Lightship	Dec. 24, 1924	6.0			Nantucket Sound	×				Barnacles, Molgula.
Hoven	Tanker	Jan. 6, 1925	8.0	7.0	1.0	New York-West coast of United States, via Panama Canal.			×		Barnacles, algæ.
Eagle 26	Patrol boat	Jan. 29, 1925	24.0	2.0	22.0	New York Harbor, Seventy-second Street	×				Barnacles, mussels.
Eagle 27	do	do	24.0	2.0	22.0	New York Harbor, Ninety-sixth Street	×				Barnacles, Molgula.
West Maximus	Freighter	Jan. 30, 1925	6.5	5.0	1.5	New York-Baltic ports				×	
Abron	do	Jan. 31, 1925	9.0	7.0	2.0	New York-Mediterranean			×		Algæ.
Sapelo	Oiler	Feb. 2, 1925	7.0	5.0	2.0	New York-Texas				×	
Sirius	Cargo ship	do	9.0	5.0	4.0	New York-West coast of United States		×			Barnacles.
Rochester	Cruiser	Feb. 3, 1925	10.0	4.0	6.0	New York-Canal Zone	×				Barnacles, osyters.
McFarland	Destroyer	Feb. 4, 1925	13.0	9.0	4.0	New York-Labrador-Central America			×		Barnacles.
West Kedron	Freighter	Feb. 9, 1925	5.5	4.5	1.0	New York-West coast of Africa			×		Minute barnacles.
Independence	do	Feb. 16, 1925	5.5	5.0	.5	New York-around the world, both canals				×	
Eastern Glade	do	Feb. 17, 1925	6.0	5.0	1.0	New York-South Africa			×		Barnacles, algæ.
Bellhaven	do	Feb. 20, 1925	41.0		41.0	New York-Staten Island	×				Barnacles, hydroids.
Eagle 45	Patrol boat	Feb. 21, 1925	24.0	2.0	22.0	New York Harbor, Bay Ridge	×				Molgula, hydroids.
Eagle 51	do	do	24.0	2.0	22.0	New York Harbor, Fire Island	×				Do.
America	Passenger	Feb. 24, 1925	6.0	5.0	1.0	New York-Cherbourg				×	
Memphis	Cruiser	Mar. 6, 1925	3.0		3.0	New York-Philadelphia				×	
Kearny	Freighter	Mar. 7, 1925	45.0		45.0	New York, Staten Island	×				Barnacles, hydroids.
Westport	do	Mar. 9, 1925	10.0	3.0	7.0	New York-Europe			×		Barnacles.
Hawthorn	Lightship tender	Mar. 10, 1925	8.0		8.0	New York-Block Island-Connecticut River			×		Do.
St. Anthony	Freighter	Mar. 21, 1925	7.0	5.5	1.5	New York-Baltic ports				×	
Cathlamet	do	Mar. 26, 1925	6.0	1.0	5.0	New York-West coast of Africa		×			Do.
Republic	Passenger	Mar. 27, 1925	12.0	11.0	1.0	New York-Translantic			×		Algæ.
Privateer	Naval yacht	Mar. 30, 1925	(?)	(?)		New York Harbor and vicinity					
Homestead	Freighter	Mar. 31, 1925	6.0	5.0	1.0	New York-India, via Suez Canal		×			Algæ, hydroids.
Western World	do	Apr. 3, 1925	7.0	6.5	.5	New York-South America				×	
Lightship	Lightship	Apr. 4, 1925	9.0			Cape May, N. J.		×			Do.

TABLE 1—Continued

Ship	Type	Date examined	Period out of dock (in months)			Waters cruised	Degree of fouling				Predominating type of fouling organism
			Total time	Time cruising	Time in port		Heavy	Moderate	Light	None	
Tulip	Lightship tender	Apr. 7, 1925	9.0	8.0	1.0	New York Harbor and vicinity			×		Algæ, hydroids.
Fox	Destroyer	Apr. 13, 1925	12.0	2.0	10.0	New York-Maine		×			Barnacles, Bryozoa.
Aztec	Tanker	Apr. 20, 1925	12.0	11.0	1.0	New York-West Indies			×		Barnacles, algæ.
Arkansas	Battleship	Apr. 22, 1925	4.5	2.5	2.0	New York-Cuban			×		Bryozoa, algæ.
The Lambs	Freighter	Apr. 28, 1925	5.0	4.0	1.0	New York-around the world, both canals			×		Algæ, barnacles.
Vega	Cargo ship	May 2, 1925	7.0	4.0	3.0	New York-West coast of United States			×		Algæ.
Penobscot	Naval tug	May 11, 1925	8.0	1.0	7.0	New York-Washington		×			Barnacles, hydroids.
West Wind	Freighter	May 21, 1925	36.0		36.0	Staten Island Kills	×				Do.
Eastern Light	do	May 25, 1925	24.0		24.0	do	×				Do.
Englewood	do	May 26, 1925	24.0		24.0	do		×			Barnacles, algæ.
Breck	Destroyer	June 2, 1925	2.0	1.5	.5	Norfolk-New York				×	
Bellepline	Freighter	June 3, 1925	24.0		24.0	Staten Island Kills	×				Barnacles, hydroids.
New Mexico	do	June 19, 1925	5.0	4.5	.5	New York-West Africa		×			Barnacles.
Heffron	do	June 20, 1925	7.0	6.0	1.0	New York-China, via Panama Canal				×	
West Humhaw	do	June 22, 1925	6.0	4.0	2.0	New York-West Africa				×	
Pategonia	do	June 29, 1925	24.0		24.0	Staten Island Kills	×				Barnacles, hydroids.

Fig. 16.—Type and amount of fouling on ships' bottoms. Many small sessile barnacles, some clusters of Bryozoa and hydroids, and numerous conspicuous stalked barnacles (Lepas)

Fig. 17.—Type and amount of fouling on ships' bottoms. A typically dense growth of hydroids

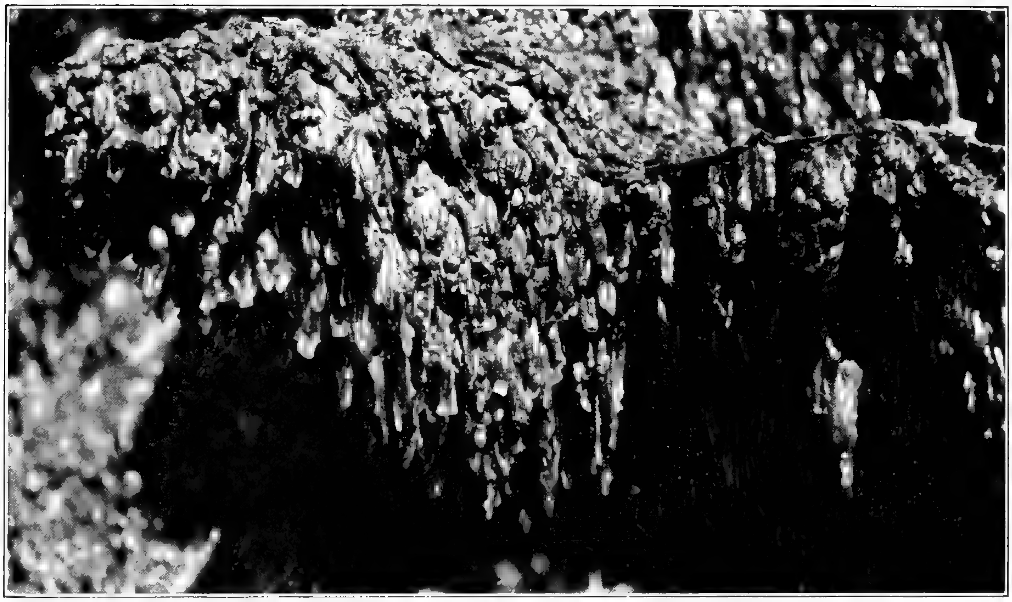


FIG. 18.—Type and amount of fouling on ships' bottoms. Large clusters of tunicates (sea squirts)

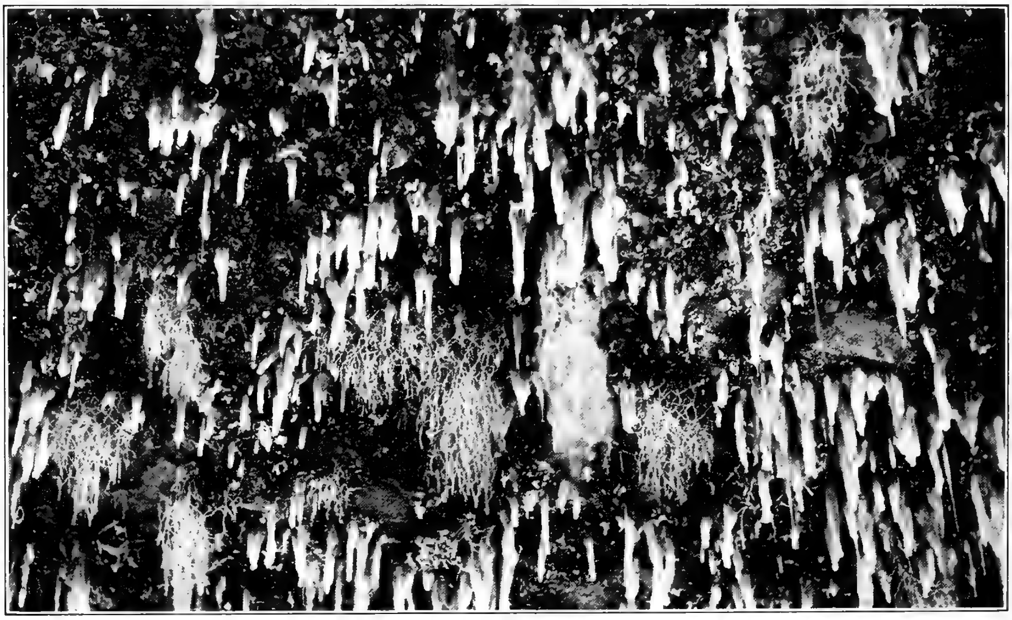


FIG. 19.—Type and amount of fouling on ships' bottoms. Numerous tunicates, typical clusters of hydroids, many small barnacles, and colonies of Bryozoa

By analyzing the data in this table regarding the extent of fouling we find that 87 per cent of all ships were fouled to some extent, and accordingly only 13 per cent were clean. A more detailed analysis of these proportions is given in Figure 20. By referring to this figure it will be seen that while 13 per cent were clean, 39 per cent were lightly fouled, 27 per cent moderately fouled, and 21 per cent heavily fouled.

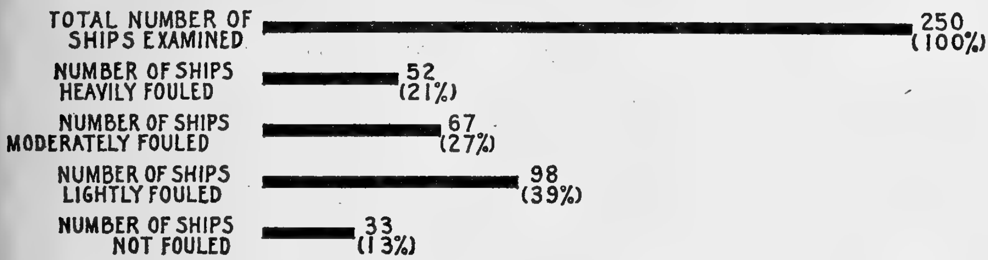


FIG. 20.—Total number of ships examined and relative number in each of the four groups classified according to the amount of fouling on each vessel

TABLE 2.—*Total amount of fouling, by weight*

Ship	Date examined	Length	Width	Draft	Number of areas measured	Size of areas measured	Amount of fouling per area	Total amount	
								Metric	United States
		Feet	*Feet*	*Feet*				*Kilos*	*Tons*
Proteus	Sept. 28, 1922	552.0	62	27.7	4	1 meter wide, water line to keel.	60 kilograms	8,000.0	8.82
Fish Hawk	Nov. 7, 1922	147.0	27	11.0	2	do	5 kilograms	415.0	.46
Wyoming	Dec. 17, 1922	562.0	93	28.5	4	1 square meter	2 kilograms	5,954.0	6.55
West Virginia	Nov. 21, 1922	624.0	97	30.5	3	do	3 kilograms	10,612.5	11.67
Leviathan	May 18, 1923	906.9	100	23.7	4	do	2.5 kilograms	9,987.0	10.98
Do	Mar. 1, 1924	906.9	100	23.7	4	do	3 grams	12.0	.013
America	Feb. 24, 1923	668.0	74	22.8	5	do	10 grams	28.2	.310
Do	Dec. 19, 1923	668.0	74	22.8	5	do	1 gram	2.8	.003

The exact amount of fouling on individual ships has been difficult to determine because of complicating conditions at the time of dry docking. A fairly accurate determination was made, however, for each of the eight ships listed in Table 2. The amount of fouling on each was determined by calculations based upon accurate measurements of the total amounts on limited areas, the sizes of which are indicated for each vessel in the above table. The total amount of fouling on the entire ship was then calculated on the basis of a knowledge of the length, width, and draft of the ship and calculation of its wetted surface. It will be seen by reference to this table that fouling was very severe on ships like the *Proteus*, a collier in the naval transport service; while a passenger ship like the *America* had only a very small amount of fouling. None of the vessels listed in this table indicates the maximum amount of fouling occasionally found on ships. This has been estimated by reliable authorities to exceed 500 tons per vessel occasionally, but fortunately few ships are now permitted to become so foul before redocking, regardless of time intervals.

TABLE 3.—*Distribution and frequency of various organisms on first 100 ships examined*

Fouling material	Proteus	Maryland	Fish Hawk	West Virginia	Parker	O'Brien	Rail	Bobolink	Rochester	Washington	Wright	Wyoming	Nevada	Kittery	Beale	Warrington	Henderson	Antares	America	Eagle 44	Eagle 48	Eagle 51	American Legion [1]	Denver	Florida	Sigourney	Cole [1]	Rowan [1]	President Monroe [1]	S. C. 103	S. C. 271	S. C. 143	Privateer [1]	Traffic [1]
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Barnacles:																																		
Balanus eburneus	×		×	×	×	×	×	×			×	×			×			×		×	×	×				×				×	×	×		
improvisus	×						×	×	×		×	×		×				×		×	×	×		×	×					×	×			
amphitrite		×											×				×							×	×									
tintinabulum													×				×							×	×									
crenatus																						×												
Balanus, sp. undetermined												×					×									×								
Hydroids:																																		
Eudendrium ramosum		×																																
Tubularia crocea			×						×									×																
sp., unidentified		×			×	×								×											×									
Campanularia amphora				×			×	×																										
portium							×																											
vorticellata																														×				
sp., unidentified	×								×					×	×	×		×							×	×					×	×		
Bougainvillia carolinensis				×																														
Perigonimus jonsii				×																														
Podocoryne sp., unidentified				×																														
Metridium sp., unidentified	×			×					×																									
Bryozoa:																																		
Bowerbankia caudata				×			×		×																							×		
Anguinella palmeta				×																														
Alcyonidium mytili	×						×																											
gelatinosum									×					×																				
Membranipora lacroixii			×				×	×	×					×											×									
sp., unidentified											×																							
Mollusca:																																		
Ostrea elongata						×		×			×															×								
Mytilis edulis					×	×																								×				
Nudibranchiata sp. ?																											×							
Annelida:																																		
Hydroides hexagonis	×		×	×		×																			×		×							
Nereis pelagica			×																															
Glycera sp., unidentified					×																													
Protozoa:																																		
Vorticellidæ				×	×			×	×	×		×			×												×							
Folliculina															×												×							
Tunicates:																																		
Molgula manhattensis		×																									×							
arenata				×	×					×																								
Algæ:																																		
Ulva lactuca				×	×			×		×																								
Vaucheria sp. ?				×																														
Enteromorpha intestinalis															×																			
sp., unidentified		×			×			×						×							×						×							
Ulothrix flaca									×					×																				
Polysiphonia nigrescens					×			×						×																				
Acrochætium sp., unidentified								×																										
Syphonales sp., unidentified								×																										
Oscillatoria sp., unidentified														×																				

[1] No record for ship.

Table 3.—*Distribution and frequency of various organisms on first 100 ships examined*—Contd.

Fouling material	East Wind 35	Arkansas 36	Argonne 37	Williamson 38	Orion 39	Cleveland 40	Eagle 54 41	Eagle 15 42	Ossining [1] 43	Natirar [1] 44	Maryland [1] 45	Reuben James 46	Camden 47	Independence [1] 48	St. Paul [1] 49	William Penn [1] 50	Leviathan 51	Half Moon 52	Rochester 53	Surinam [1] 54	Azalea 56	Sinsinawa 57	Scottsburg 58	Salaam 59	Manhattan Island 60	Pan America 61	Chester 62	Takoma 63	Edgemont 64	Majestic 65	Phalarope 66	E. A. Morse 67	Nobles 68
Barnacles:																																	
Balanus eburneus		×					×	×				×					×				×						×		×		×		×
improvisus		×			×		×	×				×	×				×												×			×	×
amphitrite	×																		×						×	×		×					
tintinabulum																			×									×					
crenatus																																×	
tulipiformis	×																																
Balanus cyprid larvæ																						×	×	×	×	×							
Balanus sp., undetermined																									×					×			
Lepas hillii													×					×															
Conchoderma aurita																		×															
Poecilasma crassa													×												×								
Hydroids:																																	
Eudendrium ramosum																											×				×		
Tubularia crocea																													×		×		
sp., unidentified		×			×								×				×										×					×	×
Campanularia sp., unidentified																	×										×		×			×	×
Metridium sp., unidentified																													×			×	×
Segartia sp., unidentified																	×										×					×	
Astrangia sp., unidentified																	×																
Bryozoa:																																	
Bugula turrita													×															×			×		
Bowerbankia caudata																										×							
Alcyonidium mytili		×																															
Membranipora monastachys													×																				
lacroixii																									×								
sp., unidentified					×		×	×									×		×								×			×			
Mollusca:																																	
Ostrea elongata																	×																
Mytilis edulis																											×		×			×	×
Annelida:																																	
Hydroides hexagonis																																	
sp., unidentified																	×					×											
Protozoa:																																	
Vorticellidæ			×																														×
Tunicates:																																	
Molgula manhattensis			×	×																							×					×	
Algæ:																																	
Ulva lactuca																											×	×	×	×			
Enteromorpha intestinalis			×																								×						
sp., unidentified		×	×							×																	×						
Ulothrix flaca																											×						
Polysiphonia nigrescens																														×			
Cladophora sp., unidentified		×																									×						

[1] No record for ship.

TABLE 3.—*Distribution and frequency of various organisms on first 100 ships examined*—Contd.

Fouling material	Edenton 69	Chinook 70	Neptune 71	McFarland 72	West Nohno 73	Saint Mihiel 74	Goff 75	Gilmer 76	S.-11 77	Sands 78	Childs 79	Surinam 80	Commack 81	Reuben James 82	Oureq 83	Eastern Leader 84	Hopkins 85	Kane 86	S.-10 87	Independence 88	Cantigne 89	Wright 90	West Irmo 91	Angelus 92	Waban 93	William Penn 94	Bird City 95	Western Plains 96	West Virginia 97	West Nestleton 98	Tulsagas 99	President Garfield[1] 100	Total
Barnacles:																																	
Balanus eburneus	X	X	X											X	X							X											34
improvisus	X	X					X	X				X			X				X		X			X	X	X		X	X				38
amphitrite					X															X										X	X		12
tintinabulum					X															X			X							X			9
crenatus									X																								3
tulipiformis																																	1
Balanus cyprid larvæ		X																															6
Balanus sp., undetermined										X	X	X						X	X				X				X						10
Lepas hillii																																	2
Conchoderma aurita																																	1
Poecilasma crassa																																	2
Hydroids:																																	
Eudendrium ramosum																																	3
Tubularia crocea																																	5
sp., unidentified		X													X				X			X		X				X					19
Campanularia amphora																																	3
portium																																	1
vorticellata																																	1
sp., unidentified		X			X		X	X							X		X	X			X							X	X	X			26
Bougainvillia carolinensis																																	1
Perigonimus jonsii																																	1
Podocoryne sp., unidentified																																	1
Metridium sp., unidentified	X	X																															8
Segartia sp., unidentified																																	3
Astrangia sp., unidentified																																	1
Bryozoa:																																	
Bugula turrita																																	3
Bowerbankia caudata	X																																6
Anguinella palmeta																																	1
Alcyonidium mytili	X														X																		5
gelatinosum		X																															3
Membranipora monastachys																																	1
lacroixii	X	X	X										X				X	X				X											14
sp., unidentified	X	X										X								X		X			X	X		X	X				16
Lepralia pertusa							X																										1
Mollusca:																																	
Ostrea elongata		X													X																		7
Mytilis edulis	X	X	X																X		X	X											13
Nudibranchiata sp. ?			X																														2
Annelida:																																	
Hydroides hexagonis																				X													8
sp., unidentified																																	1
Nereis pelagica																																	1
Glycera sp., unidentified																																	1
Protozoa:																																	
Vorticellidæ																																	10
Folliculina																																	2
Tunicates:																																	
Molgula manhattensis		X	X												X																		9
arenata																								X									4
Botryllus schlosseri			X																														1
Algæ:																																	
Ulva lactuca																																	8
Vaucheria sp. ?																																	1
Enteromorpha intestinalis						X												X						X					X				7
sp., unidentified						X	X	X			X						X	X	X					X					X		X		19
Ulothrix flaca																													X				4
Polysiphonia nigrescens																																	4
Acrochætium, sp., unidentified																																	1
Syphonales sp., unidentified																																	1
Cladophora sp., unidentified						X											X																4
Oscillatoria sp., unidentified																																	1

[1] No record for ship.

In Figure 21 is shown a comparison of the relative importance of the various kinds of fouling growths, based upon data given in Table 1. It will be seen that of the 217 vessels that were foul 152 had barnacle growths, 105 were foul with algæ,

91 with hydroids, 87 with Bryozoa, 37 with mollusks, 22 with tunicates, and 17 with Protozoa. It is clearly evident, however, that for most vessels barnacles are the most important fouling agent, while the hydroids and algæ form the next groups, in order of importance. These relations are shown in Table 3, where the occurrence of each kind of organism is tabulated for each of the first 100 ships.

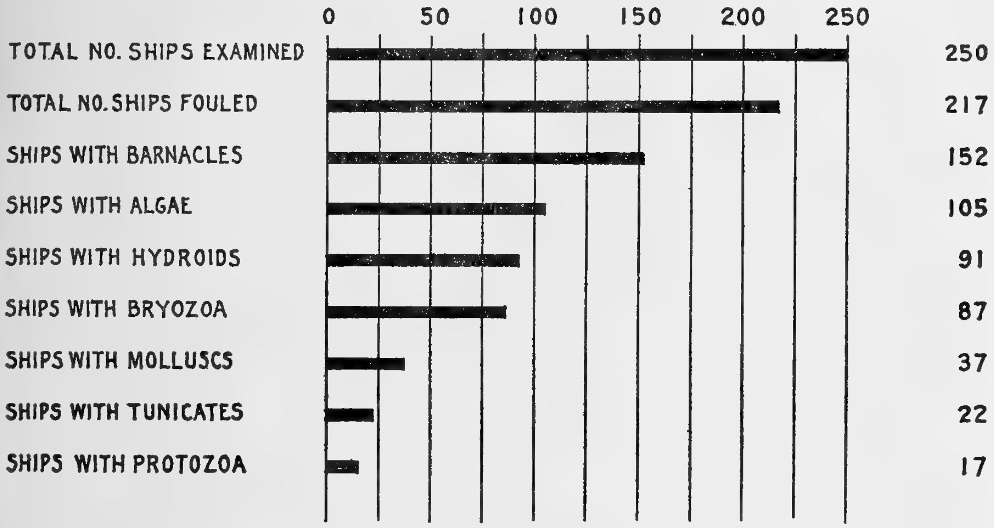


FIG. 21.—Number of ships fouled by each of several groups of organisms

EFFECTS OF FOULING

As Capt. H. Williams has very aptly stated, "considering the fact that frictional resistance is the most important element in the resistance to propulsion of practically all ships, it is surprising that there has been little investigation of the possibility of reducing skin friction to a minimum. Ship owners seem satisfied that everything is accomplished by the present system of docking ships periodically," and the subsequent cleaning of their bottoms and painting with antifouling compositions. He states, further, that "the effort to drive foul ships at full speed has burned many tons of fuel; the normal fuel consumption of ships is in excess of what this consumption would be with clean, freshly painted bottoms. While probably it is not possible to prevent fouling and the consequent increase in fuel consumption, there is room for definite improvement over existing conditions."

A few studies on the effect of fouling, as regards increased resistance, have been made. Thus, McEntee (1915) studied the relation of fouling to increased frictional resistance by submerging, near the navy yard at Norfolk, Va., a series of steel plates, each weighing 10 pounds and measuring 2 by 10 feet. After periods ranging from 1 to 12 months he removed the plates from the water, shipped them to Washington, D. C., and, at the experimental model basin, tested their resistance at speeds ranging from 2 to 8 knots. The maximum increase in resistance was found to be four times as great as when such plates are clean and freshly painted. The amount of fouling was determined in all cases, and the maximum foul condition of these plates would be roughly comparable to the condition listed as slightly less than "moderately fouled" in previous tables and elsewhere in this paper.

Although the author is not aware of any detailed studies on the effect of fouling, as regards increased resistance and consequent increased fuel consumption in ships in actual operation that are moderately or heavily fouled, recent investigations by the Navy Department show a considerable increase in fuel consumption for boats only eight weeks out of dry dock and on which only small amounts of fouling could possibly have accumulated, as the trials were made early in spring in the cold waters near Boston Harbor. The results of tests with a new submarine off Provincetown, Mass., are given in Figure 22, from which it can be seen that the speed attained with a low propeller action was decreased from 9.85 to 9.25 knots; and at high energy input (1,050 kw.) this was reduced from 15 to 14.5 knots. If there is so great a reduction in

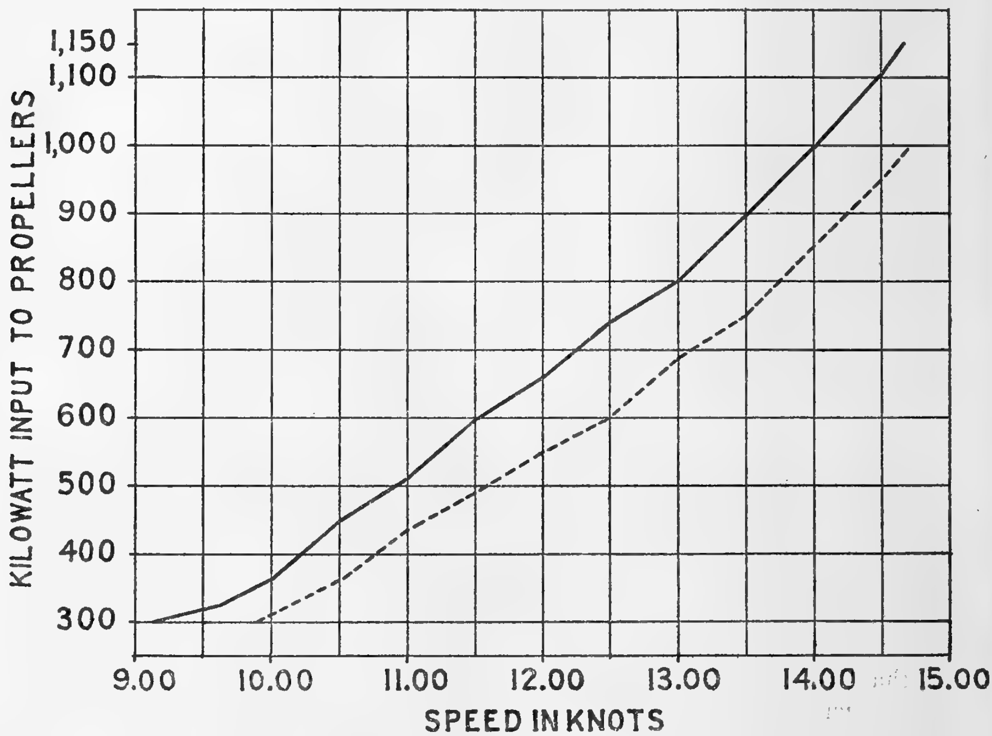


FIG. 22.—U. S. Submarine *S-34*. Standardization trials, measured mile. Provincetown, Mass., May 16–18, 1923. Vessel out of dock 56 days for run with foul bottom. Motor efficiency disregarded as virtually constant. ——— with foul bottom; -------- with clean bottom

speed when the amount of fouling is barely noticeable, the proportionate decrease in the speed of vessels heavily fouled must be very great indeed.

These results are in accord with the observations of McEntee, quoted above, who tested the resistance of recently submerged plates, with no discernible fouling, and yet found a very noticeable increase in resistance, which for the plates used in his experiments he calculated at an increase of almost 2 per cent per day.

That similar results are obtained by actual tests with ships is seen from the statement by Sir Archibald Denny, published as part of the discussions that follow the McEntee paper. Denny states that "at their shipyard on the river Leven, a tributary to the Clyde, they have found an increase in resistance at the rate of nearly

one-half of 1 per cent per day for periods as long as three months." This would mean an increase in resistance of almost 50 per cent by the end of this period, while "examination of the bottoms of the vessels in dock revealed no apparent fouling." That such practical tests are fully in accord with theory, as based upon experimental data, is shown by the additional studies of McEntee (1915) on the use of graphite, soaps, and oils as a coating for the wetted surfaces of a model ship. He found that all of these produced greater resistance than a smooth, shellacked surface.

For an analysis of the resistance of ships, the work of Hovgaard (1908) is one of the more recent, while a very excellent bibliography on this subject is given by Rigg (1915).

FACTORS THAT DETERMINE FOULING

The factors that determine the presence and the amount of fouling on a given vessel are very numerous and variable. The major factors, however, may be classified with some degree of accuracy. The season of the year, the weather, and the temperature of the water constitute one group of factors. The condition of the water in various harbors, both as to salt content and pollution, also affects fouling. The contour of the ship, which is correlated with the duty and speed of the vessel, and also the waters cruised, all affect the amount of fouling. The length of time between successive dry dockings and the proportion of this time spent in cruising or in port are very important factors. The nature of the material of which the ship's bottom is made, as well as the paints or other materials that protect it, also are of importance. Inasmuch as life is more abundant and rapid in its growth in tropical regions, it follows that boats that travel in tropical waters become more heavily fouled and in a shorter time than do similar vessels in more temperate latitudes. Likewise, ships in port during the spring and summer show heavier growths than those that are idle in port during the autumn and winter.

It will be impossible to consider all of the factors that condition fouling in all its variations, but the following pages will be devoted to a discussion of some of the major ones, with special reference to the effectiveness of paints, both as regards their poisonous properties and their protective properties from a biological consideration of the reactions to them of the larvæ of the various forms that cause fouling.

We shall discuss the relation of fouling to (1) duty, including the factor of "dry-docking period"; (2) seasons; (3) fresh waters; (4) paints and surface film; and (5) light and color.

RELATION OF DUTY OF SHIP TO FOULING

The "duty" of a ship determines, in large measure, the amount of fouling that will accumulate on its bottom. This is due to several factors, which include the effect of hull contour, of relatively much or little time spent in port, of the ship's speed while cruising, and, finally, the effect of the waters cruised.

By examining Table 1 it will be noted that there is a marked difference in the amount of fouling on ships belonging to different classes; i. e., having different duties. Thus, it was found that passenger ships with regular schedules were by far the least foul of any group. This applies not only to vessels plying between America and Europe, but to those carrying trade from New York to South American ports as well, and can be stated as a general rule.

Freight vessels and most of the active naval vessels form the next class of ships. These ships frequently lie in one port or another from one to three weeks, or even longer, and offer ample opportunity for a dense "set" of fouling growths to take place. The degree to which these organisms continue to grow depends very largely upon the amount of time in excess of 10 days that is spent in any one port and to an equal degree upon the successive ports visited after the acquisition of the original "set." If these ports should be in close proximity, the growths will continue to develop as if the ship were in the original port (with some exceptions), but if considerable distance (500 miles or more) separates them, most, if not all, of the fouling is killed, and if less than 2 weeks old almost all will drop off when dead.

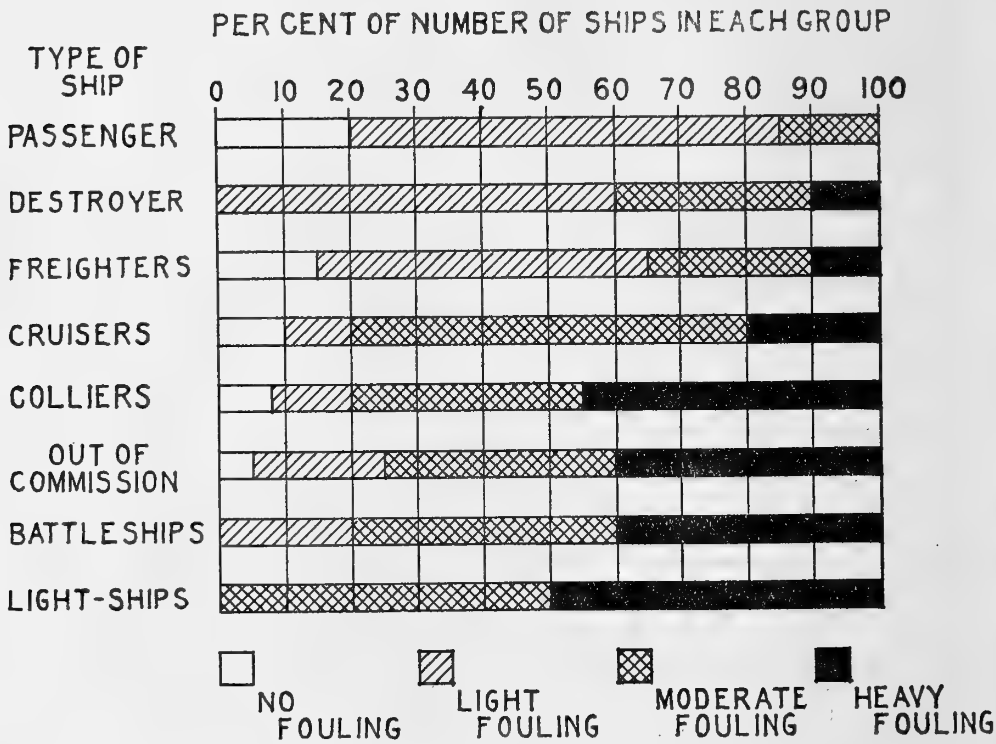


FIG. 23.—Relation between type (and related duty) of a ship and the amount of fouling, disregarding factor of time

Another class of ships, including commercial ships lying idle in port either for overhauling, repairs, or other reasons, as well as many of our naval craft (in peace times), forms the group that is fouled most heavily. This is due largely to the fact that frequently they lie in a given port for from 1 to 6 months, affording ample time for the original set of fouling material to develop and grow, so that all types of sessile marine growths that normally occur in that harbor frequently are found in luxurious growth on the bottoms of such ships.

An analysis of the data in Table 1, as regards the relation of fouling to the above classes of vessels, is given in Figure 23, which shows the percentage of the total number of ships in each of the eight classes, grouped according to the relative amount

of fouling on each. It will be seen at a glance that passenger ships average a very light amount of fouling, while lightships and battleships show a very heavy growth. The percentages given for each group do not show an exactly comparable relationship, because data gathered from all the sources are included. If one were able to exclude all data from the Philadelphia Navy Yard, with its polluted, fresh-water harbor, and also omit those ships that enter dry dock after an unusually short interval (because of accident), the relative percentages in each group would show a steady and proportionate increase in amount of fouling.

However, in any chart of this kind more than one factor is represented. The fact that the average docking interval for passenger ships is about 7 months, for freighters about 8 months, for naval craft about 9 months, and for lightships about 11 months, must be taken into consideration. This factor, however, will be discussed separately below. Regardless of many of these complicating factors, the uniform difference in the amount of fouling is of real significance and, as will be shown, is probably related more to the effect of the relative amount of time spent in port than to any other one factor.

Having seen that there is a significant difference in the amount of fouling on ships belonging to the various groups, an analysis of some of the factors that determine this difference will be considered. Since the materials for construction are comparable, the paints usually the same, and the environmental factors, such as seasons, ports, and temperature, are similar in the main, the really significant differences are clearly related to the different duties of these vessels, and this relation to fouling can be analyzed by consideration of four main factors: (1) Hull design, (2) speed of ship while cruising, (3) dry-docking period and use of intervening time, and (4) the routes or waters cruised.

HULL AND CONTOUR OF SHIP

The construction of any ship plays a considerable part in the matter of fouling. The amount of fouling rarely is uniformly dense over the various portions of the hull. This is due not only to differences in structural relations of the various parts of the hull but to specific characteristics of the fouling organisms in attaching in definite zones. Thus, we find that there is a very definite and clearly defined vertical gradation noticeable in growths on ships' bottoms. Certain forms, like Enteromorpha and some varieties of Balanus, are found characteristically in a rather narrow zone around the vessel and extending from the water line to a depth of about 3 feet. Hydroids, ascidians, and the stalked forms of barnacles are found rarely in this zone. This, however, is the zone most commonly fouled, for in almost all classes of lightly fouled vessels this was the only region fouled. Often it is covered with a dense growth of algæ, whose filaments often extend 5 to 6 inches. In such thickets one often finds a bevy of animals, including such forms as amphipods, annelids, isopods, and even canceroid crabs (probably Panopeus). Occasionally this algal zone extended much deeper than usual. On several ships this growth extended from the water line for fully 10 feet, almost to the bilge keels. It has been impossible to correlate these few cases with any seasonal variation as suggested by Hentschel (1923).

Below the algal zone one finds a scattered growth of barnacles and incrusting Bryozoa on almost all ships that are lightly fouled, but on such ships these growths usually are very sparse, especially on the more perpendicular sides of the hull. However, on all parts not so perpendicular as aft (on the "quarter" or near the "run," etc.) these growths often were noticeably more abundant. As previously noted, some ships that were otherwise clean had small amounts of growths only in the seams formed by the overlapping of the steel plates. (See fig. 24.) On most ships barnacles and Bryozoa were found here, if at all. On some, as the *Paul Luckenbach* (June 12, 1924), large clusters of worm tubes (Hydroides) were found in these seams.

The third vertical zone would include those growths that occur on the more horizontal portion of the hull—the true bottom of most ships. In the case of heavily fouled ships, this portion was also the most heavily coated. Hydroids are found in great abundance, while mussels, Ascidia, and often barnacles also are found here in great quantities. In the case of moderately fouled ships, this region is again most heavily coated, as a rule, with sessile barnacles, hydroids, and Bryozoa, and if from certain routes, with stalked or goosenecked barnacles. In the case of but lightly fouled ships, the growths here were of secondary importance to the algal zone but were always most severe in the region directly under the bilge keels and in the "run" of the ship. The factors that determine this distribution are numerous, no doubt, but some may be pointed out at this time, of which several will be discussed under separate headings.

The presence of the algal zone only at the upper limit of growth is determined rather largely by the fact that these organisms are dependent upon sunlight for continued existence and growth. Light also may play a part in determining the activities of the larvæ at the time of setting, and so determine the location of later growths. The distribution of animal life is affected by the factors that determine the place of attachment of the young larval forms as well as by the conditions providing the food necessary for continued growth. The effect of too strong a current of water, as when a vessel is cruising, probably may cause many of the more tender growths to be torn off. This undoubtedly accounts in part for the presence of growths in the seams behind the overlap of the steel plates in vessels that are in constant service. It is a fact that most barnacles, hydroids, and tunicates attach in largest number below the bilge keel and on other shaded parts of the bottom. This would indicate that relative light intensity plays some part in determining the place of attachment on the bottom.

In view of these considerations, it will be seen that the contour of the vessel is an important factor in the matter of fouling. Flat-bottomed ships of shallow draft often are more foul than boats of similar design but greater draft; while vessels designed so as to permit the effective sweep of the water while cruising to play on the entire surface usually are more free from fouling under similar conditions than are vessels with deep "runs."

Directly associated with the type of hull and the contour of the ship is the factor of speed of the ship while cruising. That this factor has some effect on the amount of fouling can not be doubted, but evidence on this point has been very difficult of obtainment without complications. The tremendous pressure exerted on the sides and prow of a vessel as it progresses at the rate of 30 knots undoubtedly

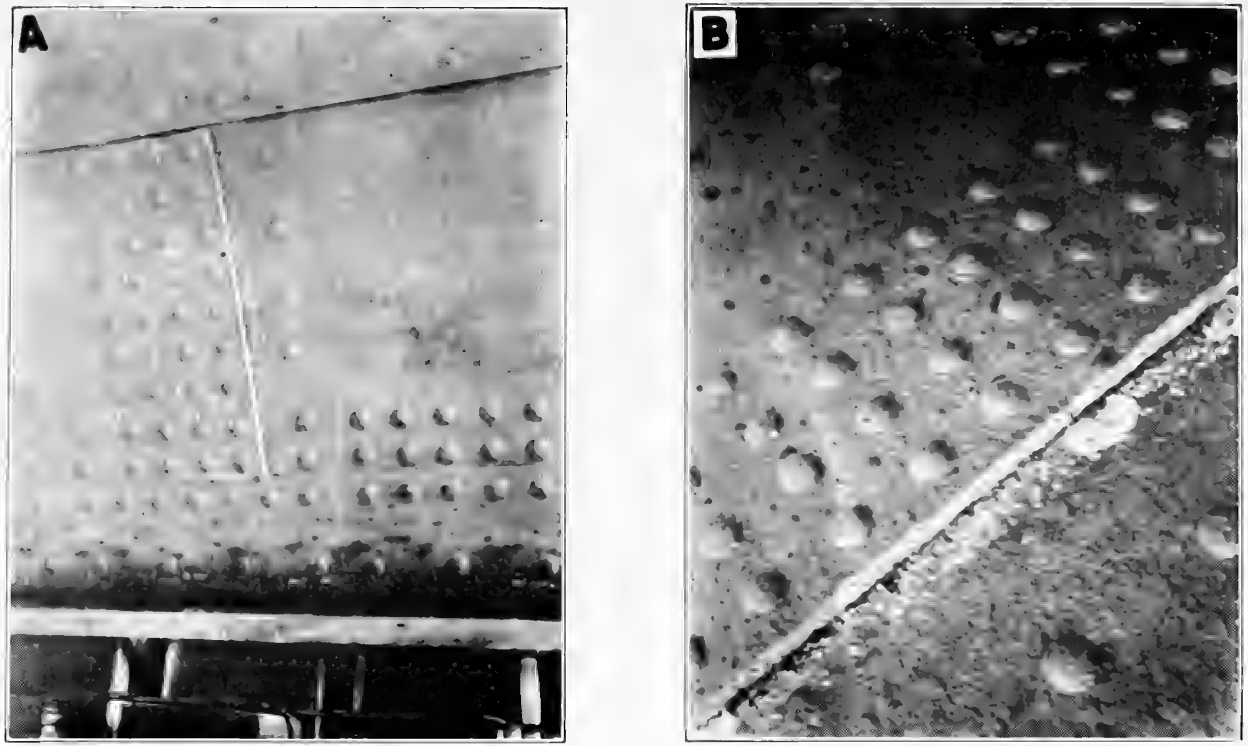


FIG. 24.—Relation between type of hull design and fouling. Views of the *Leviathan* in dry dock at Boston, February 27, 1924. **A,** several steel plates, showing characteristic location of fouling growths. **B,** enlarged view, showing presence of barnacles and Bryozoa in the seam formed by the overlap of the plates

kills most of the living organisms attached to it in exposed places. As indicated previously, the most usual place for fouling to be found on rapidly cruising vessels (passenger ships) was in the groove made by the overlapping of the metal plates of the hull. Here, then, is a case where the effect of friction through water is much reduced or entirely absent, and a merely local growth of fouling results. The noticeable absence of hydroids, tunicates, and other relatively soft-bodied organisms on rapidly cruising vessels indicates that such forms probably can not withstand the pressure, and consequently only shelly growths, such as barnacles and seruplids, are found on such vessels.

LENGTH OF PERIOD BETWEEN DRY DOCKINGS

The amount of time spent in port, in relation to the amount of time spent under way, obviously is related to the duty of the ship. It has long been known

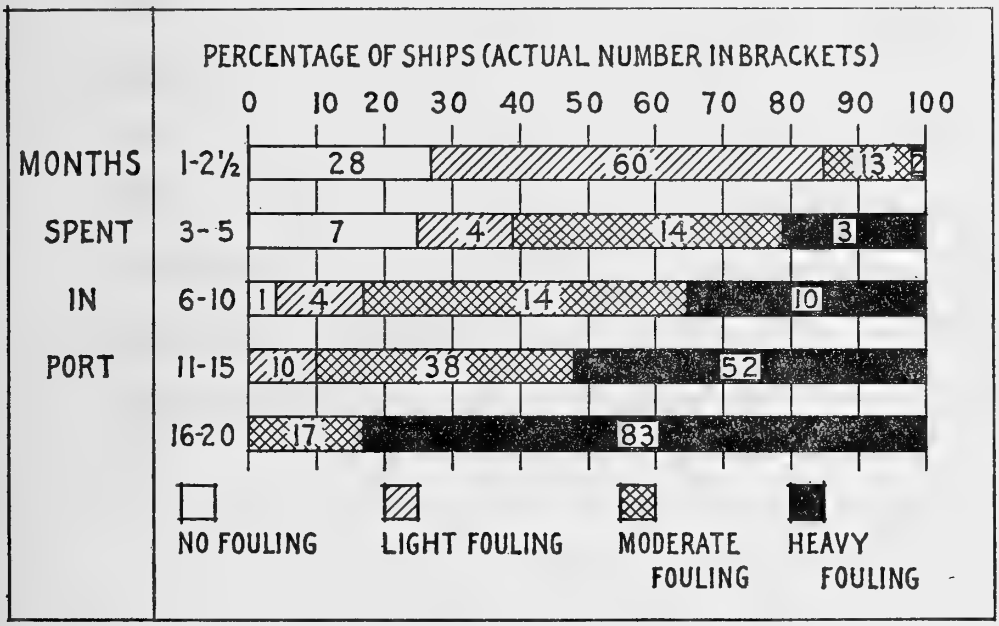


FIG. 25.—Relation between the degree of fouling and the amount of time spent in port between dry dockings

that while idle in port boats frequently accumulate heavy growths of fouling; while similar vessels, on the high seas during an equal period, remain relatively free from fouling. In the past this fact has been associated more with the length of the period that elapsed since the previous dry docking than with the relative amount of cruising done during a given period, a relationship that is of secondary importance only, as will be shown.

From the records of the ships that have been considered in this study, it has been estimated that passenger ships spend more than 60 per cent of their time cruising, while freighters spend an average of about 40 per cent of their time on the high seas. Naval craft vary greatly in this regard, but from the data given in Table 1 it can be seen that destroyers spend about 30 per cent of their time cruising,

cruisers about 20 per cent, battleships about 15 per cent, and colliers about 10 per cent, while it will be realized that lightships and "out-of-commission" ships spend virtually none of their time cruising.

That this factor is of great importance can be seen from a careful study of the list of ships, their docking periods, cruising time, and amount of fouling, given in Table 1. It has been considered desirable, however, to present this information more fully and compare it from several points of view.

Accordingly, in Figure 25 the amount of fouling in relation to the time spent in port, regardless of all other factors, is represented in the form of a diagram. As can be seen from this diagram, fouling increases in direct relation to the amount of time spent in port.

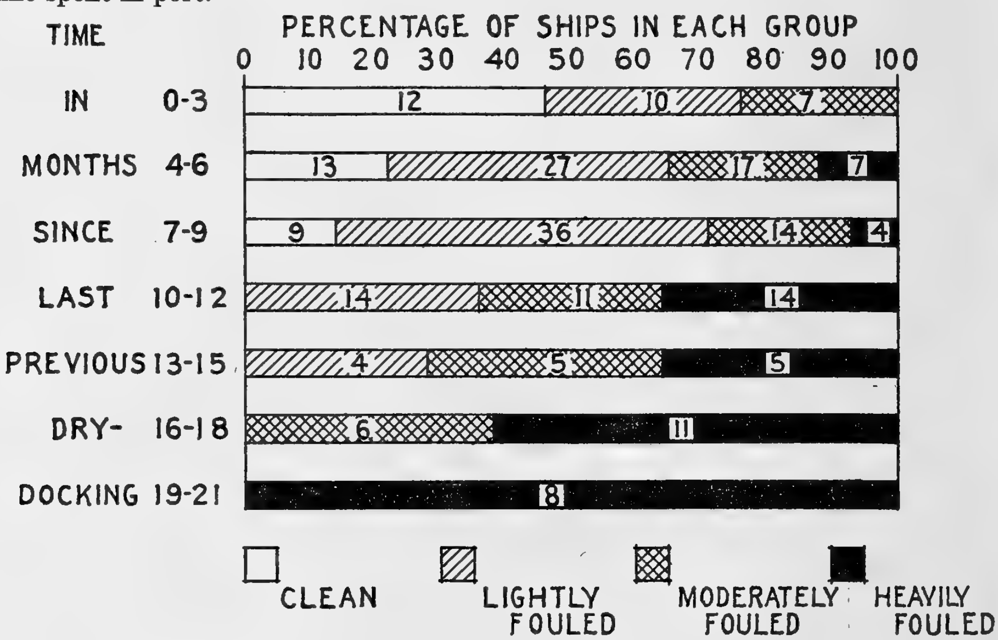


Fig. 26.—Relation between amount of fouling and amount of time between dry dockings

In Figure 26 the amount of fouling in relation to the total period that elapsed since the previous dry docking is shown. It can be seen, by referring to this diagram, that there is a fairly steady increase in the amount of fouling with the lapse of time, regardless of all other factors. Although this diagram presents only relative values, and at best approximate, it shows clearly, however, that the rate of fouling is virtually constant from the moment one dry-docking period ends to the time the next begins. (If the protective paints used have a definite "length of life" for efficiency as an antifouling agent, as is generally maintained, then there should be a marked turn at some point in the diagram, presumably after six or eight months, on the basis of customary dry-docking schedules.)

In Figure 27 is shown the relation of fouling to the amount of time spent cruising. This diagram is the reverse of that shown in Figure 25 and will serve to emphasize the significance of cruising in its effect on fouling. It will be seen that the amount of fouling is decidedly less the longer the period of time spent cruising.

That this is due not so much to the actual effect of cruising as to the fact that such boats are not in harbor sufficiently long to accumulate heavy growths is seen by comparison of this diagram with those given in Figures 25 and 26.

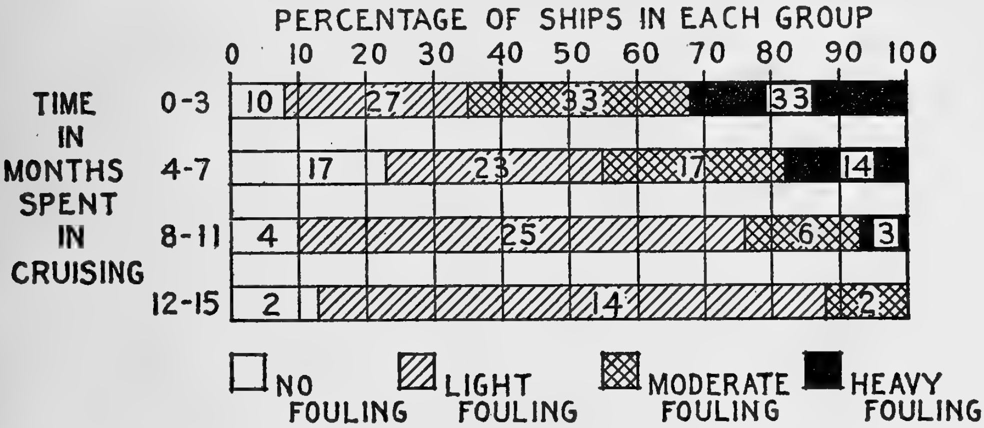


FIG. 27.—Relation between time at sea and amount of fouling

In Figure 28 is shown a combination of Figures 26 and 27, indicating a more accurate relationship between cruising and fouling. As indicated, this table shows

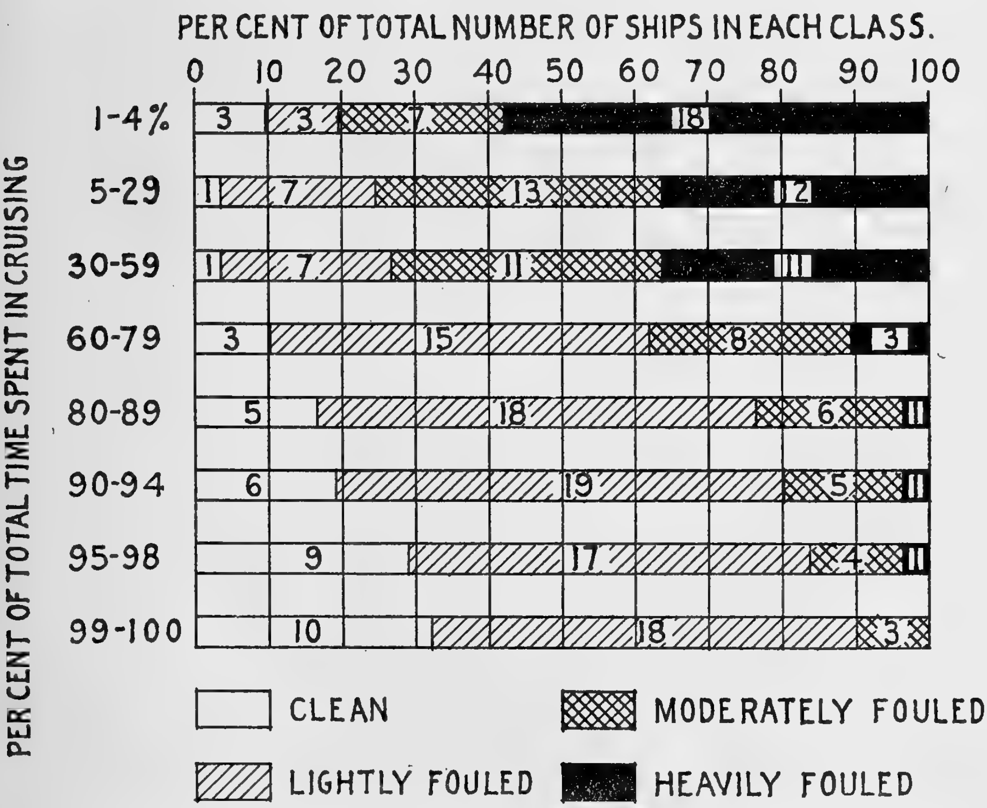


FIG. 28.—Relation between the amount of fouling and the per cent of total time since last dry docking spent in cruising

the relation of the amount of fouling to the amount of time spent at sea. It will be seen easily that this relationship is constant and that the proportions appear to vary inversely as the percentage of time spent cruising.

In Table 4 is shown a classified list of the various types of ships, indicating the number in each group, with their respective amounts of fouling in relation to the length of the last dry-docking period. Of the ships that docked within three months after a previous dry docking it will be seen that in all groups, excepting the battle cruisers, the majority of the ships were clean or only lightly fouled (for those docking), while in the next three months (i. e., from three to six months after previous dry docking) the majority were found to be in the classes of lightly or moderately fouled ships. It is also of interest to note that in columns 6 and 7, the periods longer than 18 months, the preponderance of heavily fouled vessels is very conspicuous, especially in the case of vessels "out of commission."

From these tables it is seen easily that the time between dry-docking periods is of great significance, but the use made of this time, either in cruising or in port, is of even greater importance. It can be seen, in addition, that the amount of fouling increases with the length of time that elapses since the previous dry docking (fig. 26) but becomes proportionately less with any increase in the percentage of time spent cruising. (Fig. 28.)

TABLE 4.—*Analysis of the difference in docking periods for diverse types of ships and the relative amount of fouling on these ships, grouped according to length of time elapsed since previous dry docking*

[H, heavily fouled; M, moderately fouled; L, lightly fouled; N, no fouling; X, aberrant cases, due to putrid waters of the Philadelphia Navy Yard]

Class of vessel	1 to 3 months	3 to 6 months	6 to 9 months	9 to 12 months	12 to 18 months	18 to 24 months	24 months
Colliers and miscellaneous naval craft		2 M	1 H 4 M 2 L	4 H 1 M 3 L	2 M 1 L	1 H	
Battleships	1 L	1 H 3 M	1 M 2 L		2 H		
Destroyers	2 L 1 N	3 L 1 N	1 M 4 L	2 H 3 M 2 L	2 L	1 H	
Passenger vessels	1 L		5 L 3 N	1 L			
Freighters	1 M 2 L 2 N	5 H 10 M 15 L 6 N	1 H 3 M 14 L 2 N	3 M 4 L	1 L		
Cruisers	3 M	2 M 2 N	2 M 1 L	3 H	1 M		
Out of commission	1 L	1 L 1 N		3 H 3 M 1 L	3 H 2 M 1 L	3 H 3 M 1 LX	6 H. 2 LX.
Lightships			1 H 1 M 2 L	3H 1 M			

WATERS CRUISED

Associated directly with the duties of a vessel is the cruising record, indicating by its log where the vessel has been and what ports were visited. Thus, of the boats examined for this report the passenger vessels were on the trans-Atlantic service or the South American or Mediterranean routes, while the freighters had an even wider range of routes. Some of those examined plied regularly between New York and the west coast of South Africa, others between New York and the Mediterranean or New York and our west coast, or even New York and the East Indies.

Naval craft, as a rule, do not have regular definite routes, consequently much of the data in Table 1 is of little use in an analysis of the relation between routes and the amount of fouling.

In those cases, however, where it has been possible to study the effect of different routes traversed by different ships it has proved to be one of the most interesting problems encountered during the entire study. Just as the flora and fauna of the Tropics is different from that of the Arctic regions, and just as the trees of California are different from those found in Maine, so the growths attaching to ships in the China Sea are markedly different from those attaching in the North Atlantic or from those of any other geographic region. In other words, each vessel, if foul, shows at the time of docking, by the growths found on its bottom, a visible record of its cruise.

This report is not the place for a discussion of the geographic range of various species of organisms but a discussion of their effect on fouling will be in order.

One of the effects which was noticed early and was confused on many occasions is that found when a ship fouled in a tropical port arrives in a northern port, or vice versa. On such ships all growths are dead, either in a putrid condition or leaving behind only their skeletons or shelly growths as a reminder of the once abundant life. (*Nevada*, January 5, 1923.) Even ships moving from one port to another 500 miles away usually exhibited a similar state. (*Leviathan*, May 18, 1923, Norfolk to Boston.)

While it can be stated as a general rule that vessels that remain only a few days in one port and then move on to another remain free from fouling, there are certain noticeable exceptions. This is the case with freighters of the United States Shipping Board, which ply between New York and the west coast of Africa. Almost without exception these vessels were found to be heavily fouled, in spite of short dry-docking periods (five to six and one-half months), and in spite of the fact that rarely did they remain in any one port for more than three or four days. By an examination of Figure 29, which indicates the geographical relationship of the routes taken by these ships, it will be seen that although they moved from port to port almost daily yet these ports are very close together and most are in the same latitude; that is, they are in a similar geographical area, with environmental conditions comparable if not identical. It is evident, consequently, that the effect of change of port on growths causing fouling would be very slight, if any, and it is very evident, as seen by the records of examination of such ships, that the barnacles and hydroids that attach

69861—28——3

in these ports continue to grow in the neighboring harbors just as rapidly and luxuriantly as if the vessel had remained in the original port during the entire interval. It is doubtful if a series of ports can be found anywhere else in the world having so similar environmental factors that determine the ecological conditions for rapid growth of fouling organisms.

In contrast with this route, vessels returning from South American ports are frequently clean, or at best only lightly fouled. Vessels in the trans-Atlantic service, whether passenger or freight, rarely show heavy fouling unless delayed in some port for a considerable length of time.

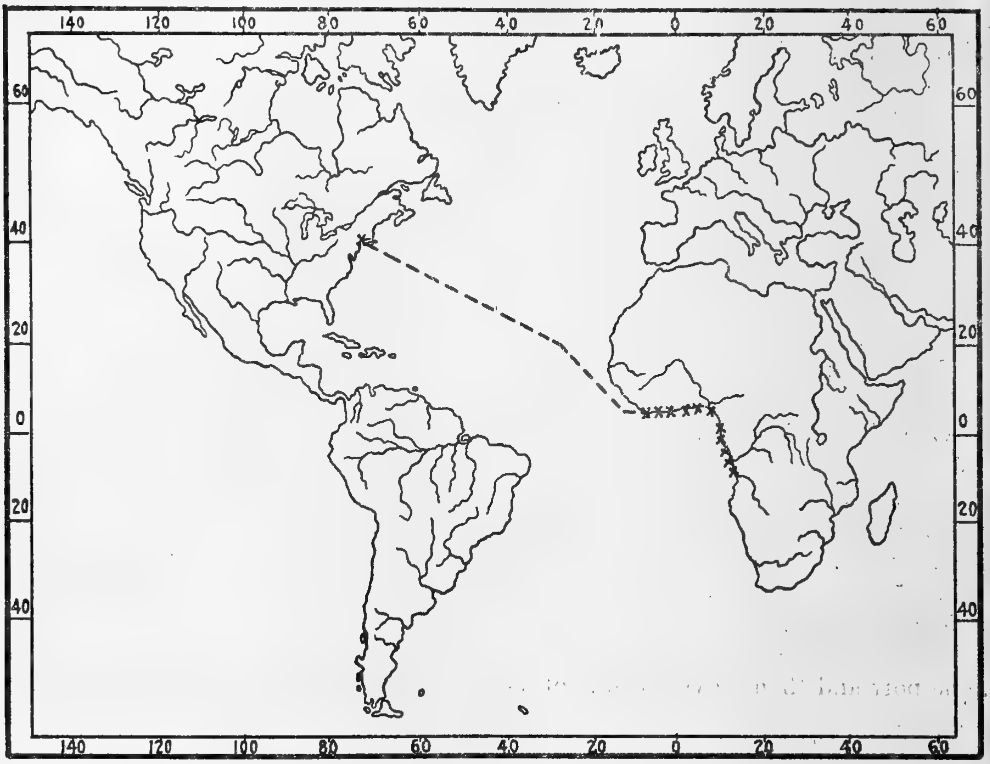


FIG. 29.—Route taken by certain of the freighters operated by the United States Shipping Board. Many of the ports are in the same latitude and all are in a similar geographic area

The type of fouling is very specific for certain routes, or at least for certain waters. Thus, naval vessels that practice in southern drill grounds at Guantanamo Bay, Cuba, West Indies, have characteristically large numbers of *Balanus improvisus*, *B. amphitrite*, and *Membranipora lacroxii.* Vessels that remain in the western Atlantic, north of the Chesapeake, have characteristic growths of *B. eburneus* and Tubularia. Vessels that visit the ports of the east coast of South America usually have growths of *B. tintinabulum* and *B. amphitrite*, although if no extended time was spent in these ports, or if these were river ports, such vessels would have clean bottoms.

It can be stated definitely from all data available that vessels that visit ports in tropical regions usually are more foul than those that ply more temperate zones.

Also, both from an examination of the logs of ships and a study of the organisms found on their bottoms, that ships foul almost entirely while in harbor, and that these growths usually die if the vessel leaves the original port where fouling first attached, provided such movement carries the vessel to a port at some distance from the original one (see *Maryland* and *Nevada*) or into a port with different ecological factors, such as fresh water, polluted water, or any water considerably different in temperature and related salt content, as found in most ports 500 miles or more apart.

It is thus seen that the log of a ship tells in a large measure, to those able to read it, the degree of fouling likely to be found on a ship at any given time, and an examination of the fouling material from the bottom of a vessel shows fairly accurately where the vessel has been and how long it remained in various harbors.

SEASONS AND RATE OF GROWTH

That fouling would occur more severely at certain periods of the year than at others is self-evident to all who study nature's laws. It is a well-known fact that for most animals there is a limited breeding season, occurring, as a rule, but once each year. Similar periodicities are found in most marine organisms, some of which have been carefully studied; as, for example, the oyster (Brooks, 1880), the clam worm, Nereis (Lillie and Just, 1912), and the Chitin (B. H. Grave, 1922). It seems probable that all living organisms that are subject to marked seasonal changes in climate, such as temperature and salt content of the water for marine organisms, as well as to seasonal changes in food, either in kind or amount, have seasonal periodicities related to reproduction. Very little is known, however, regarding the exact details of this question as it applies to those organisms that cause fouling on ships' bottoms. Such knowledge involves a careful study of the breeding periods of many species of these organisms, as well as an accurate knowledge of the habits of the larvæ from the time of hatching to the time when they attach and begin life as sessile organisms.

However, some studies that have a bearing on this problem have been published recently. Caswell Grave (1920 and 1923) has studied the activities of the larvæ of four species of tunicates. He found that all had limited breeding periods during the summer months for the region about Woods Hole, Mass. He was able to demonstrate that in the species studied the larvæ have a relatively short, free-swimming period, varying from 1 to 28 hours. Of this time, during the first portion, in all cases, the organisms reacted toward light and against the influence of gravity; but toward the end of the free-swimming period all reversed these reactions and were negative to light and positive to gravity. At the end of the short, free-swimming period, these organisms become attached, metamorphose, and develop at a rapid rate into the typical adult form.

The recent work of Fish (1925) is also of interest in showing the periodicity in the presence of different types of barnacle larvæ and other fouling agencies in the waters immediately south of Cape Cod. His data show that the larvæ of various barnacles are found for almost 10 months of the year. It is for only about five of these months, however, that the cyprid forms are found. Since of the forms listed only *Balanus crenatus* and *B. eburneus* are serious fouling agents, and since they attach

only while in the cyprid stage, it is apparent that fouling by barnacles could occur only from July to late September in this region. Of the three hydroids listed in his report, which are occasionally found on ships' bottoms, it is of interest that the majority are also present as larvæ during the late summer months.

Although a few additional scattered references to similar data could be listed, they are extremely meager, and there are almost no data available on the subject of seasonal distribution and periodicity (especially with reference to the larvæ) that are at all comparable to the complete study of this subject with reference to the boring mollusks (Teredo and Bankia), which so severely attack all marine structures, especially piling, buoys, and wooden vessels. (See Atwood and Johnson, 1924.)

SEASONAL PERIODICITY

During this investigation, while examining the bottoms of more than 250 ships, it has been possible to secure some additional data, but relatively few are of an

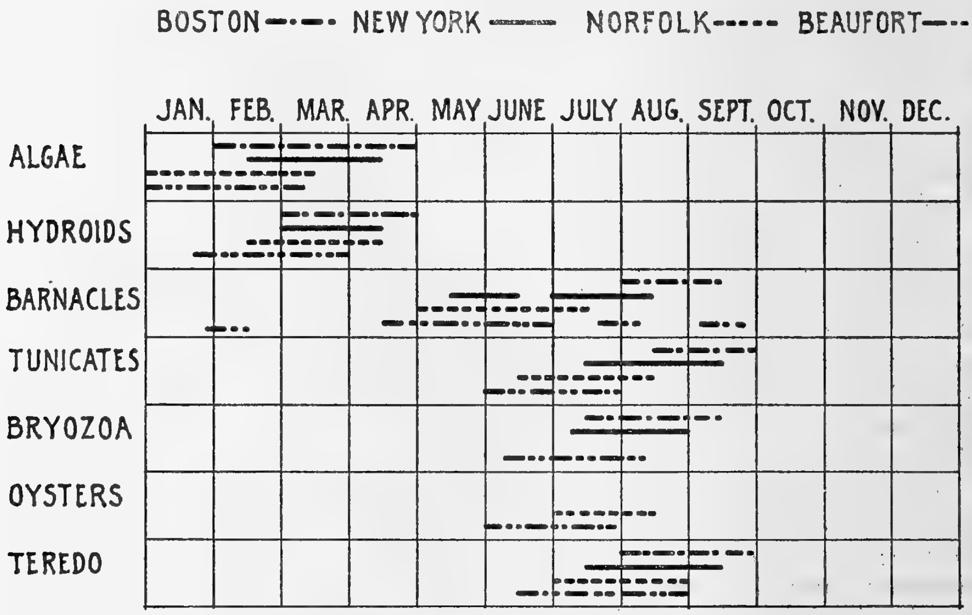


FIG. 30.—Prevalence of the larvæ of organisms that cause fouling at Boston, New York, Norfolk, and Beaufort, N. C. From data gathered from ships' bottoms and test panels

exact nature because few ships are docked within 90 days of their previous docking, consequently it was only on rare occasions that the exact time of attachment for specific organisms could be determined. However, from the few ships that docked within 30 days of their last previous dry docking, as well as from vessels that were in a given port continuously, it has been possible to prepare some incomplete but fairly accurate charts for fouling in the harbors at Boston, New York, and Norfolk, and at Beaufort, N. C. These are given in Figure 30.

By referring to this chart it will be seen that the periods of active fouling vary with the kinds of fouling. Thus, the hydroids and algæ are late winter and early spring forms; while many of the barnacles, the oyster, and the bryozoan Bugula are late spring and summer forms, and some barnacles and the tunicate Molgula are late summer or early autumn forms. Each of these is found earlier in southern

waters, as at Beaufort and Norfolk, than in the cooler and more northern waters, as at New York and especially Boston.

It will also be noted that the barnacles and some of the others have a more extended breeding period in warm waters than in those north of New York, where these periods are limited sharply for most organisms. It is apparent, however, that for the barnacles and the more serious types of fouling, measures employed to prevent their attachments should be most effective during the early summer months, varying the date according to the latitude of the locality.

The above data are admittedly not accurate in every detail but serve to indicate the significance of such studies. A more comprehensive study of this problem has been begun by the author, and preliminary results are appended as a preliminary report on seasonal fouling, as determined from panels submerged in various ports by naval vessels.

Early in the course of this investigation it was realized that accurate data for determining the periods of active fouling could not be gathered by a study of ships' bottoms alone, and it was accordingly recommended that such information for various harbors be ascertained by submerging panels from vessels visiting such ports. In conformity with these plans, 10 sets of panels were prepared by the Navy Department (New York and Norfolk yards), and these were issued to as many ships with instructions to submerge a set of two panels in each port visited, provided the vessel remained there three days or longer.

Of these panels only three sets have as yet been received for biological study. Of these one set had but three boards and showed no results. The third set received was likewise small and completely dried out when received so that results were difficult to evaluate. The second set, however, showed definite and significant results. These panels had been submerged by the U. S. S. *Sirius* and represent fouling conditions for limited periods at the San Diego, Mare Island, Bremerton, and New York Navy Yards. The data are tabulated in Table 5. By referring to this table it can be seen that fouling is severe at Mare Island in October, while it is very slight during June. At San Diego growths attach in moderate numbers in June and July, while no fouling, apparently, occurs during November. These data would indicate that at Bremerton, Wash., fouling is moderate in late June, while at the New York yard none occurs during late September. It is interesting that all of the above data substantiate general conclusions drawn from examination of ships' bottoms.

TABLE 5.—*Results obtained, with reference to seasonal fouling, from panels submerged by the "Sirius"*

Panel No.	Date of submersion	Date when removed	Place of submersion	Depth submerged	Current and condition of water	Type of fouling
				Feet		
1	May 31	June 5	San Diego	16	Sluggish, fairly clear	Slimy scum; few barnacles.
2	do	do	do	16	do	Few barnacles and hydroids.
3	do	do	do	16	do	Do.
4	June 10	June 18	Mare Island	16	Fair current, very dirty	Single hydroid.
5	do	do	do	16	do	Few hydroids.
6	do	do	do	16	do	Scum only.
7	June 23	July 11	Bremerton	16	Sluggish, clear	15 minute barnacles.
8	do	do	do	16	do	25 barnacles on panel.
9	do	do	do	16	do	125 barnacles on panel.
10	July 23	July 28	San Diego	16	Sluggish, very clear	Few minute barnacles.
11	do	do	do	16	do	Barnacles and few hydroids.
12	do	do	do	16	do	A single hydroid.
13	Sept. 16	Sept. 23	New York Navy Yard	16	No current, very dirty	Clean.
14	do	do	do	16	do	Slime only.
15	do	do	do	16	do	Do.
16	Oct. 21	Oct. 30	Mare Island	16	Fair current, dirty	500 minute barnacles.
17	do	do	do	16	do	25 barnacles and few minute hydroids.
18	do	do	do	16	do	1,000 minute barnacles and few hydroids.
19	Nov. 22	Nov. 28	San Diego	16	Sluggish, fairly clear	Clean.
20	do	do	do	16	do	Do.
21	do	do	do	16	do	Do.

RATE OF GROWTH

The rate of growth of various organisms is of importance in any study of the factors that determine fouling, because of the fact that organisms become much more resistant to changes in their environment as they grow older (within limits) and as such are not killed off by the moving of a vessel from one port to another as easily as when the growths were young and succulent, and also because of the fact that increase in size increases the resistance of the ship.

It is surprising, perhaps, to learn that barnacles grow to sexual maturity in less than 90 days and often attain large size in less than that time, as can be seen by referring to Figure 31 *F*, which shows the size of some barnacles collected from the *Nevada* after she had spent 60 days in the harbor at Rio de Janiero. Figures 31 *A* to *E*, represent the rate of growth of barnacles at Beaufort, N. C.; and in Figure 32 is shown the amount of fouling that accumulated on a piece of wood at this harbor in 60 days. Very little accurate information is recorded regarding the rate of growth of these forms, although B. H. Grave (1924) has made a recent study of some of the forms that cause fouling, but these results have not been published as yet.

FRESH WATER

HISTORICAL DATA

It is a firmly established belief among mariners that if a "fouled vessel is placed in fresh water the growths on its bottom will be removed and the boat again become clean." When the cruises for vessels were less exactly timed than at present, experienced sea captains often put into a fresh-water harbor for this single purpose; and even to-day ships passing through the Panama Canal are known frequently to spend an extra day or more in the fresh-water lakes, and it is commonly understood that sea captains are anxious to have their vessels in fresh-water ports whenever possible. According to Capt. Henry Williams (1923), however, unfortunately there is no definite information on this subject.

It is known that certain marine organisms can and do survive in fresh water; as, for example, the eel, the salmon, or the shad, all of which spend a part of their lives in fresh water and the remainder in salt water. Similarly, such algæ as Enteromorpha and Cladophora live indifferently in fresh and salt waters; but such forms are very few in number in comparison to the vast number of marine organisms that soon die if placed in fresh water.

Among the organisms that cause fouling, almost all are strictly marine forms with but a small percentage able to survive in brackish waters. There can be no doubt, then, that many of these organisms are killed if the vessel to which they are attached is transferred to fresh water for a period of time sufficient to secure this effect.

DATA FROM SHIPS

During the course of this investigation it was apparent on many occasions that the unusually clean condition of the boat was no doubt explicable on the basis of visits into fresh waters. Thus, in the case of the *Western World* (March 8, 1924) its regular

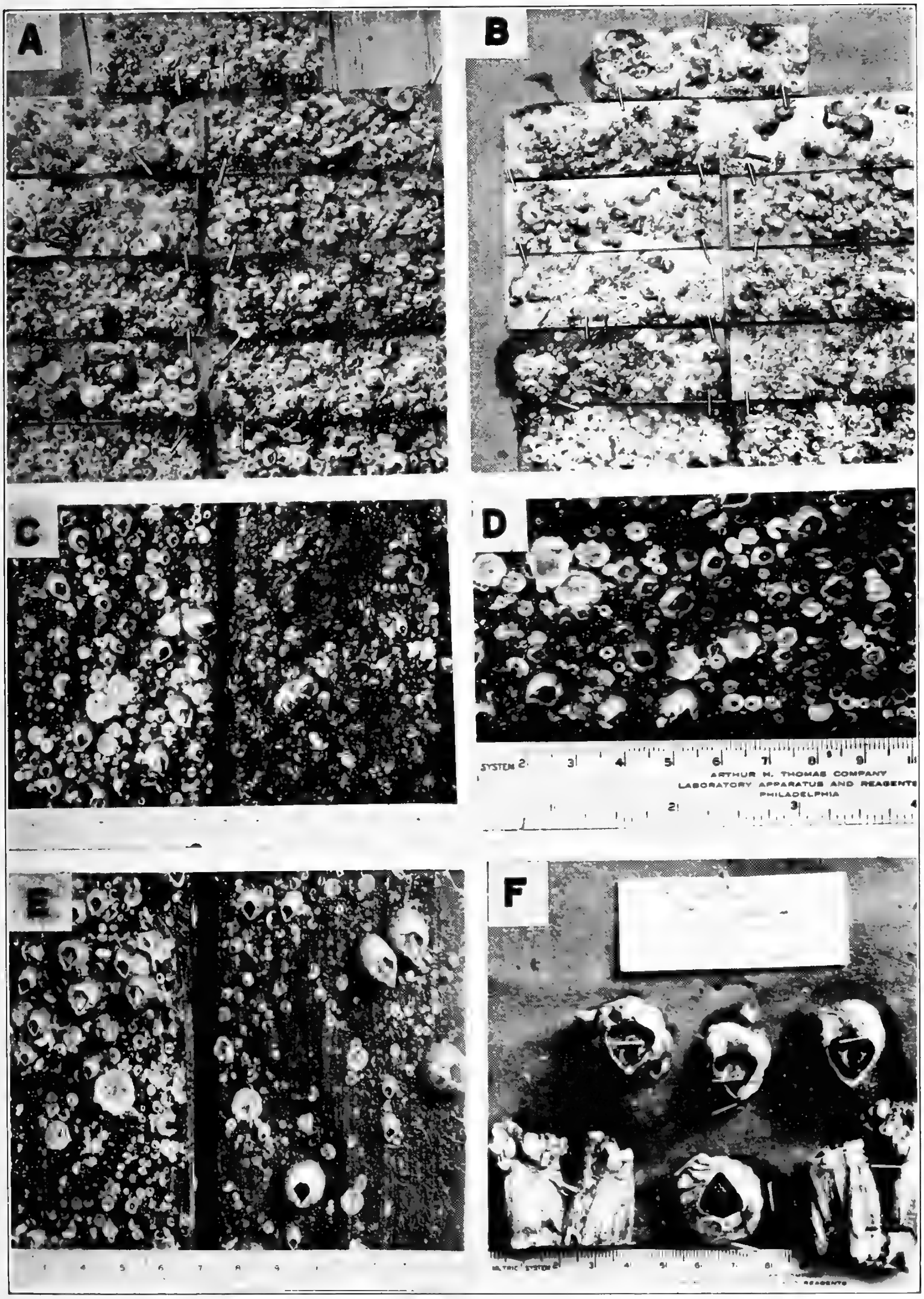


FIG. 31.—Rate of growth for barnacles. **A** and **B**, one month's growth of *Balanus eberneus* on glass slides 3 by 1 inch, June 5 to July 4, 1924, at Beaufort, N. C. **C** and **D**, two months' growth of *B. eberneus* on wood at Beaufort, N. C., May 17 to July 16, 1924. **E**, three months' growth of *B. eberneus*. May 17 to August 17, 1924, at Beaufort, N. C. **F**, approximately three months' growth of *B. tintinabulum* from Rio de Janiero, as collected from the hull of the U. S. S. *Nevada*

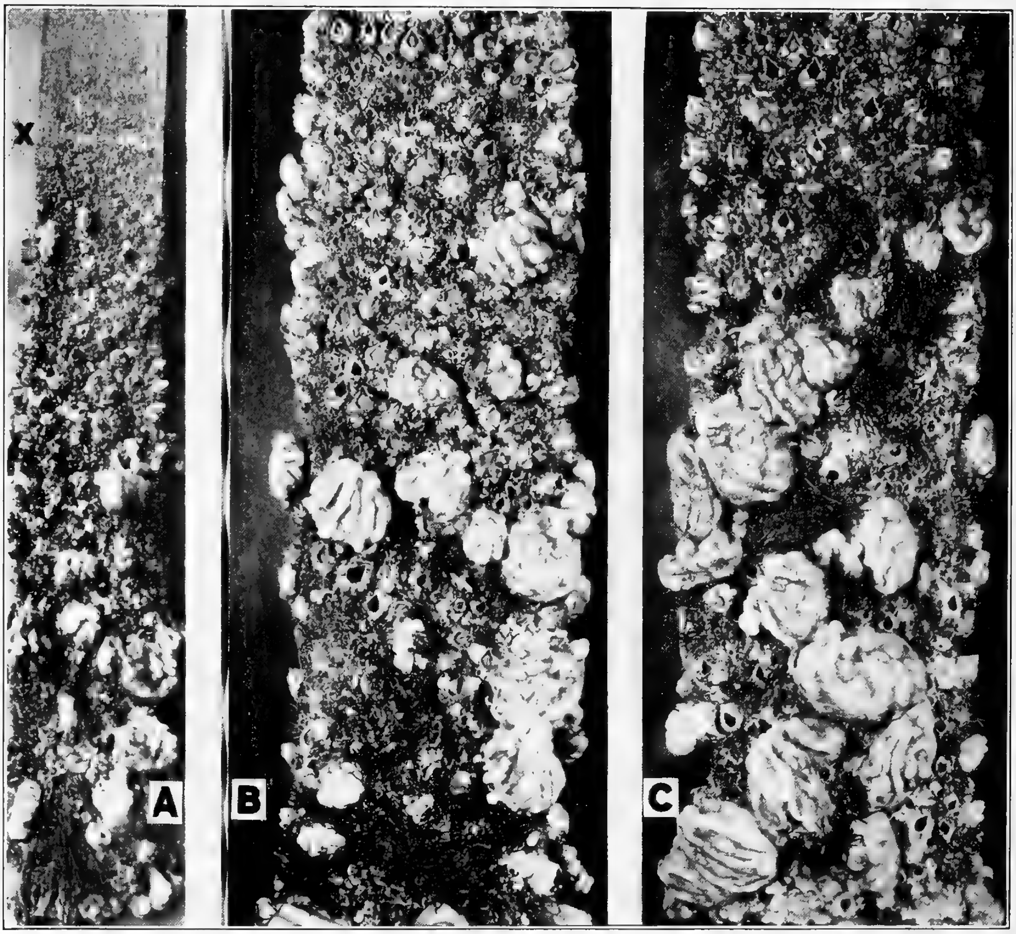


Fig. 32.—Amount of fouling accumulating within 60 days (May 15 to July 15, 1925) on a board 4 inches wide by 1 inch thick and 26 inches long. **A,** entire board, indicating average low tide line (x); **B** and **C,** enlarged views of growths

visit to Sante Fe (Argentina), far up on the Salado River, very probably explains the absence of fouling on this route, while vessels that do not visit fresh-water ports usually acquire heavy fouling. Similar explanations would account for the conditions found on the *Eastern Pilot* (March 25, 1924), the *Zarembo* (April 11, 1924), and also the *Eastern Sword* (April 11, 1924).

The lightship tender *Hawthorne* (March 10, 1925) was found to be almost clean, in marked contrast to most vessels of her group. The fact that she spent considerable time in the Connecticut rivers probably explains this condition, on the basis of the effect of fresh water.

While there can be no doubt that fresh water kills many of the organisms that cause fouling, yet that does not imply in any way the natural conclusion that such ships would then be clean. On the contrary, many ships have been observed where the fouling growths were very probably killed by the entrance of the ship into a fresh-water harbor, but fouling on such ships often remained severe for a considerable period. The shelly growths of barnacles, oysters, Mytilis, and even of Bryozoa, and the chitinous "stems" of hydroids have been seen on ships that had been in the fresh-water harbor of Philadelphia for more than 12 months. The most notable example of this is the case of the destroyers *Parker* and *O'Brien* (November 28, 1922), where many barnacle shells were scraped from their bottoms after more than 20 months in polluted fresh water. It is thus evident that although fresh water kills the growths that cause fouling, it does not remove them or clean the ships unless such growths are succulent or very young, in which cases the entire ship probably is cleaned by this process.

EXPERIMENTAL DATA

In order to ascertain more exactly the period that it is necessary a vessel spend in fresh water in order to secure such desired results, the following experiments were conducted.

Various types of organisms were removed from their normal salt-water habitation and placed in containers, through which a slow current of fresh water passed constantly. A continuous circulation of water was found necessary, both to supply the required oxygen and to prevent putrefaction from affecting the more resistant organisms. Death point was determined if after transfer to normal environment resuscitation did not occur.

In Table 6 is given the list of the organisms tested and the period of exposure necessary to kill. The first column indicates the time at which the first were observed to succumb, and the second column indicates the maximum period during which these organisms were able to live in fresh water. The number of trials is also indicated in each case, many organisms being used in each trial.

It will be seen from this table that many of the organisms that cause fouling can be killed by transfer to fresh water for a period of 24 hours. This is especially true for most larval and young forms. It will be noted, however, that several important organisms such as *Balanus eburneus*, Ostrea, and Enteromorpha, often are not killed in less than four days, although in several tests it was found that the larvæ and younger forms of all but the last of these were killed within that period.

TABLE 6.—*Illustrating the resistance of marine organisms to the effects of fresh water, indicating in hours the length of time that certain forms, common on ship's bottoms, were able to live in circulating fresh water*

Organism	Number of trials	Minimum period	Maximum period
		Hours	*Hours*
Balanus eburneus	4	72	96
B. amphitrite	5	12	24
B. balanoides (1)	4	36	48
Chthamalus stellatus (2)	2	48	60
Tubularia crocea	2	12	24
Eudendrium	2	6	12
Obelia geniculata	1	6	12
Membranipora sp.?	4	12	24
Bowerbankia gracilis	3	6	12
Ostrea elongata	2	48	96
Enteromorpha (3)	3	72	?

NOTE.—(1) and (2) are not common on ship's bottoms but are listed for the sake of comparisons. (3) is a variable, depending upon the previous environmental conditions. Death determined by inability to revive after being returned to original environment.

Accordingly, it can be assumed that much fouling is killed by a stay of one day in fresh water. If the growths present are all young, a larger percentage will be killed and most or all of them will disappear completely. If on the other hand, they are mature forms of more than two or three months, many of such growths may not be killed in less than 72 or 96 hours; and even if killed, their shelly structures will still remain, often for a long period of time. Inasmuch as the resistance to a ship is caused by these structures, whether alive or dead, little benefit will accrue from such visits to fresh water, except that these growths will no longer increase in size. It is accordingly evident that fresh water will kill most forms that cause fouling but will not remove many of the growths already present, unless these are minute and not heavily calcified or chitinized.

POISON PAINTS, METALS, AND SURFACE FILMS

POISON PAINTS

The practice of painting ships' bottoms has been in vogue so long that its value hardly can be questioned. As stated in the introduction, ships probably have been painted since the first ship was launched, but the nature of this paint has varied from time to time. These paints have been utilized as much or even more for the preservation of the wood or metal of which the hull is made than for the prevention of marine growths. Thus, on steel vessels to-day it is the practice to cover the ship first with a coat of "anticorrosive" paint and subsequently with a second coating of some "antifouling" paint. The former is for the preservation of the metal while the latter is applied in the hope of preventing the growth of fouling agencies, and contains the various poisons used for that purpose.

Before metal vessels came into use poison paints were resorted to primarily to prevent the attachment of the marine borers, which, even in recent times, have caused so much destruction to piling and other harbor equipment (see Atwood and Johnson, 1924) and which, until steel ships were first employed, caused even greater damage to the hulls of wooden vessels.

That copper poisons are especially efficacious in preventing the attachment of the young larvæ of these forms, provided the paint has been applied recently, is acknowledged generally. Many copper and mercury salts are extremely toxic to most animal and many plant organisms. It would be supposed, naturally, that these would be effective against those organisms that cause fouling, although no experiments to prove such a contention have been tried, as far as the author can learn, on any of the organisms as they exist at the time of attachment. Recently, Bray (1923) studied the resistance of the earliest larval stage of a single barnacle (*Balanus eburneus*) to various poisons, the results of which study will be considered below.

That the efficacy of poisons has been doubted by many is indicated by the following quotation from Lewes (1889), of the Royal Naval College of Great Britain:

> On examining the conditions under which a vessel is put when coated with a composition which relies for its antifouling powers on metallic poisons only, we at once see the reasons which must make such a coating of little or no avail. In the composition we have drastic mineral poisons—probably salts of copper, mercury, or arsenic—which have been worked into a paint by admixture with varnishes of varying composition, and each article of poison is protected from the action of sea water by being entirely coated with this mixture; that this must be so is evident, or the composition would not have sufficient cohesive power to stick on the ship. As a rule, care is taken to select fairly good varnishes, which will resist the action of sea water for, perhaps, two or three months before they get sufficiently disintegrated to allow the sea water to dissolve any of the poison; whilst even with the accidental or intentional use of inferior varnishes, three or four weeks will pass before any solution can take place and any poison liberated to attack the germs. A ship is dry-docked, cleaned, and her antifouling composition having been put on, she goes probably into the basin to take on cargo. Here she is at rest and, with no skin friction or other disturbing causes to prevent it, a slimy deposit of dirt from the water takes place, and this, as a rule, is rich in the ova and germs of all kinds of growth whilst the poisons in her coating are locked up in their restraining varnish and are rendered inactive at the only period during which they could be of any use.
>
> After a more or less protracted period the ship puts to sea, and the varnish being aided by friction of the water the poisonous salts begin to dissolve or wash out of the composition; but the germs have already got a foothold, and with a vessel sweeping at a rate of 10 to 12 knots through the water the amount of poison which can come in contact with their breathing and absorbing organs is evidently so infinitesimally minute that it would be impossible to imagine it having any effect whatever upon their growth. If the poison is soluble, it is at once washed away as it dissolves; if it is insoluble, then it is also washed away, but there is just a chance that a grain or two may become entangled in the organs of some of the forms of life and cause them discomfort. As the surface varnish perishes, the impact of the water during the rapid passage of the vessel through the water quickly dissolves out or washes off the poisonous salts and leaves a perished and porous, but still cohesive, coating of resinous matter, which forms an admirable lodgment for anything that can cling to it; and by the time the vessel lays-to in foreign waters, teeming with every kind of life, the poison which would now again have been of some use is probably all washed away, and a fresh crop of germs is acquired, to be developed on the homeward voyage, and a "bad ship" is reported by the person who looks after her docking. It is evident that a poison, even if it had the power of killing animal and vegetable life in all stages, could only act with the vessel at rest, unless it were of so active a nature as to burn off the roots and attachments of the life rooted to it, and if it did this, what, may I ask, would become of the protective composition and the plates of the vessel? And I think it is also evident that any poison so used must be under conditions in which it is very unlikely to be in a position to act when it might do good.
>
> The practical proof, given by experience, that poisons alone are unable to secure a clean bottom soon led many inquirers to the conviction that it was exfoliation in the case of copper which had acted in giving fairly good results, and in many compositions the attempt has been made to provide a coating which will slowly wash off, and, by losing its original surface, shall at the same time clear

away germs and partly developed growths and so expose a continually renewed surface, in this way keeping the bottom of the vessel free from life. There is no doubt that when this is successfully done a most valuable composition will result, but the practical difficulties which beset this class of antifoulers must not be overlooked. In order to secure success, the composition must waste at a fairly uniform rate, when the ship is at rest, and also when she is rushing through the water; and this is the more important in the case of service vessels, as in many cases they spend a large percentage of their time at anchor, or in the basins of our big dockyards. If a composition is made to waste so rapidly that it will keep a vessel clean for months in a basin, then you have a good composition for that purpose; but send the vessel to sea, and under conditions where you have a higher temperature, and the enormous friction caused by her passage through the water exerting its influence upon the composition, and you will find that the coating which did its work so well for six months at rest in the basin will, in the course of one month under these altered conditions, be all washed away, and fouling will be set up. Noting this result, the manufacturer renders his composition more insoluble—less wasting—and so obtains a coating which, when the vessel is in motion, scales just fast enough to prevent fouling, and good results at once follow; the composition is then put on the same or other vessels, and they take a rest in the basin, and bereft of the aid of a higher temperature and the friction of the water, the composition ceases to waste fast enough, and bad results at once have to be recorded. (Gardner, 1922–23, pp. 47 and 48.)

Apparently little consideration has been accorded the fact that all growths that attach to ships have a protective layer of material, frequently of a composition similar to limestone, between their bodies and the film of paint, and that in adult forms, at least, food is taken in from a very considerable distance from the sides of the ship. It is apparent to anyone with knowledge of the structure and habits of the animals that cause fouling that the only time a poison carried in a paint film could possibly be effective must be at the time of attachment.

When it is realized that barnacles (which are, as previously demonstrated, the most serious factor in fouling) attach by means of long antennæ, and that they do not take any food or even have any functional mouth during the period of attachment (that is, until metamorphosis has been completed) it can be seen that the effect of poison must be either as a direct irritant during this process or else the poison must be in such concentration in the surrounding water that the little organism, after attachment and subsequent metamorphosis, is poisoned by it with the food it takes from a distance of at least 1 millimeter from the surface of the paint. The amount of poison necessary to build up a concentration sufficient to be toxic at so great a distance, when submerged in an ocean of water that is usually in motion, and to hold such a concentration for a period of weeks or even months, as is demanded, would probably need to be much greater than the amount used. Even as early as 1867 Charles F. T. Young questioned the efficacy of poison paints, as can be seen from the following quotation (p. 68):

"It has been remarked somewhat dogmatically that for protecting iron vessels against corrosion and the adhesion of barnacles the use of a poisonous paint is in all cases indispensable, and this paint must be slightly soluble in water." But he maintains that "The primary requisite qualification for all paints or patented compositions laid over the bottoms of iron ships is necessarily the 'preservation' of the iron."

It is accordingly apparent that the use of poisons as antifouling agents for steel ships has been based either entirely on a priori evidence, without adequate foundation, or else is a hold over from the custom of painting wooden vessels, and its efficacious use can be legitimately questioned.

The effects of many kinds of commercial paints have been observed during this investigation, but not in sufficient numbers to make it advisable to contrast their effectiveness, except in the comparison with the "Norfolk standard" used by both the Navy and the Shipping Board, whose vessels comprise more than 90 per cent of those examined in this investigation. It can be stated, however, that no paint, with the possible exception of "Moravian" (*Litchfield*, April 10, 1924), has proved to be superior to the "Navy standard." The "amalgamated" was used on the *Benguela* (September 4, 1924), and this vessel was much more severely fouled than the *West Hestleton* (August 12, 1924), both of which, as seen from their records, had similar duties, cruising records, and itineraries, and were operating at almost the same season of the year, a factor that may have had some influence.

The effect of the "Red Hand" paint was seen on such ships as the *Hopkins* and *Kane* (December 7, 1923), *Goff* and *Gilmer* (November 21, 1923), and *Fox* (April 10, 1924), as well as on others; but adequate comparisons could not be made. In several cases, however, similar ships with similar duties but with "Navy standard" paint showed somewhat less fouling than the above.

The "International" paint was used on several lightships and tenders, including the *Relief* (April 24, 1924), *Northend* (June 2, 1924), *Lotus* (August 7, 1924), *Hawthorne* (March 10, 1925), and *Lightship 108* (April 4, 1925), and in most cases these were badly fouled. No comparison could be made, as none were painted with the "Navy standard."

The problem of continued effectiveness of paint is one that has been pondered long. The number of factors that enter into the problem of fouling apparently have clouded any accurate determination of this matter; and even in this investigation with respect to only a few ships could the question be answered positively, as negative data were inconclusive.

In the case of the *Maryland* (October 12, 1922), a heavy set of barnacles had occurred within the 70 days that elapsed after a previous dry docking, and in the case of the *Sturtevant* (November 20, 1924), a similar heavy growth of *Balanus improvisus* occurred during the 90 days after the previous dry docking. In the few other cases of short docking intervals (usually occasioned by some accident to the ship) light fouling, due to algæ, was observed. It is evident, however, from these two cases, as well as from the experimental test plates, that fouling frequently occurs even within 20 days of the time of painting, indicating that the effectiveness of the poisons apparently was lost by that time.

Many steel panels coated with various poison paints have been submerged, both by the Navy Department and by the American Society for Testing Materials, in order to determine the relative efficiency of such paints as antifouling means.

Although the final report on the experiments conducted by the Navy Department has not been seen by the writer, the report of Bray (1923) contains a list of many of the poisons used and the period of exposure when examined. These poisons were used as ingredients of paint films and were employed in concentrations of 4, 8, and 12 per cent. The following selections will give some idea of the range of materials tested: HgO, ZnO, CuO, naphthalene, zinc cyanide, poke root, NaOH, cupric oxide, sodamid, thymol, hydroxylamine sulphate, strychnine sulphate, quinine sulphate, uranium nitrate, Portland cement, T. N. T., phenol, capsicum, arsenated bakelite,

aluminum sulphate, barium sulphate, sodium silicate, sodium chloride, hexamethylenamine, and copper sulphate. Many of them showed heavy fouling in less than 150 days, although a few, especially the mercury and copper oxides, showed less than the other materials tested. In a tentative report regarding these results Captain Williams (memorandum, July 25, 1923) stated that "of all the different substances tried the most effective are mercuric and cuprous oxides."

The American Society for Testing Materials has appointed a subcommittee (No. 23) for investigating antifouling paints. Five annual reports have been submitted, which include the results of many experiments with submerged panels and some tests on ships' bottoms. One definite result that they record is that "differences in fouling and corrosion are as appreciable in underwater paints by varying the vehicle as they are by varying the pigment." This fact would indicate the relatively minor effect of the toxic agents and the major importance of the condition of the paint film. Their final recommendations to date indicate a conclusion only in regard to the toxic compounds to be employed. They recommend as follows:

Antifouling paints shall contain, in each gallon of paint, copper and mercury in not less than the following amounts for varying service of ship:

Service	Copper	Mercury
	Ounces	*Ounces*
General	14	7
North Temperate waters	25	1.5
South Temperate waters	20	5
Tropical waters	14	14

The compounds of the metals are not specified, excepting that they "shall be present in the form of compounds which are not soluble in distilled water at 20° C. to a greater extent than 1 part per 15,000 parts of water, by weight (0.067 per cent = 0.00067)."

Effect of poison on larval barnacles.—Bray (1923) has studied the effect of various poisons in differing concentrations on the first larval stages of one of the barnacles that causes fouling (*Balanus eburneus*). He collected large numbers of the newly hatched nauplii and tested their resistance to known dilutions of many supposedly poisonous substances. The actions of the nauplii were carefully noted under a microscope, and the time taken to bring about complete cessation of movement was considered to be the amount of time necessary for the given solution to exhibit its toxic effects. In Table 7 the results of some of his experiments are shown. The author states that these data may be "interpreted very diversely, according to the particular conception one has of the fouling process and the time and manner of the action of the toxic agent or the anticorrosive film." While virtually all were effective at saturation, this was not the case for such compounds as cobaltous oxide and carbonate, both of which are fairly soluble in sea water, or for such compounds as antimony trioxide and copper carbonate, which are almost insoluble. "Some are very effective at high concentrations but rapidly lose their toxicity on dilution—e. g., arsenious pentasulphide and calcium fluoride." Others, though but slightly soluble, "seem effective at a great dilution—e. g., copper cyanide, mercury arsenate, phenyl arsenious oxide; and especially worthy of note is clorvinyl-arsenious oxide."

TABLE 7.—*Resistance (in minutes) of larval barnacles (nauplii) to several concentrations of various compounds (from report of A. W. Bray)*

Toxic agent	Percentage strength of solution								
	100	50	25	10	5	1	0.1	0.01	0.001
Mercuric chloride	0	0	0	0	0	0	2	5	60–90
Mercuric oxide	0	-----	-----	5	-----	27	130	280	[1] 24
Mercuric arsenate	1	-----	-----	6	-----	20	84	270	480
Copper O-nitro benzoate	1	-----	-----	5	-----	13	300	-----	-----
Copper P-nitro benzoate	0	-----	-----	14	-----	124	-----	-----	-----
Lead O-nitro benzoate	0	42	89	280	-----	-----	-----	-----	-----
Ferric O-nitro benzoate	0	82	241	-----	-----	-----	-----	-----	-----
Cuprous cyanide	22	-----	-----	-----	-----	-----	-----	-----	-----
Cupric cyanide	10	26	72	94	121	221	372	467	-----
Paris green	64	149	313	316	-----	516	-----	-----	-----
Cupric chloride	0	-----	-----	0	-----	5	8	34	150
Cuprous chloride	0	-----	-----	25	-----	-----	-----	-----	-----
Picric acid	0	-----	0	2	-----	163	-----	-----	-----
Zinc cyanide	0	18	39	220	-----	-----	-----	-----	-----
Barium arsenate	315	-----	-----	-----	-----	-----	-----	-----	-----
Phenyl arsenious oxide	0	0	0	0	-----	3	24	57	-----
Chlor vinyl arsenious oxide	0	0	0	0	-----	2	10	23	90
Diphenyl arsenious oxide	2.5	32	58	270	-----	-----	-----	-----	-----
Diphenyl amine arsenious oxide	56	120	-----	-----	-----	-----	-----	-----	-----
Napthalene	30	70	-----	105	-----	-----	-----	-----	-----

[1] Hours.

Thus, it is seen that Bray has shown that certain compounds have a very toxic effect on the earliest larval stages of barnacles, provided the concentration is sufficient in the medium surrounding the organism to have its maximum effect. It must be understood at this time that the barnacles attach by means of long antennæ, and that in the case of mercurial compounds a concentration of more than one part per hundred thousand must be maintained in order to have any effect at all. With the entire ocean as a solvent, and less than 14 per cent of an extremely thin film to act upon, it seems questionable if such poisons can build up a concentration sufficient to be lethal for any considerable period of time. Of course, it is remotely possible that chemical action with sea water might have some effect, as suggested by Gardner (1922, p. 55). He states:

> The toxicity of free substances such as mercury and copper compounds to young organisms does not necessarily give a true indication of their toxicity when mixed with other ingredients of a paint, and the influence of the component parts of the sea water upon the toxic substance through longer periods may render it more or less toxic by dilution or by chemical interaction * * *. It is well known that when two substances are mixed together in varying proportions the resulting mixture is frequently more toxic than the same quantity of either component if used separately. The "why" of this action is not known; it is merely an empirical result.

However, this type of speculation has no evidence whatsoever for its support and perhaps is indicative of the methods sometimes employed in the preparation of antifouling paints.

Many paints have been tested by actual application on the bottoms of ships, both by the United States Navy and by the American Society for Testing Materials, through cooperation with the United States Shipping Board. In such tests the vessel to be painted usually was marked off into four divisions, and the forward port quarter and aft stern quarter were painted with the test paint while the other two quarters were painted with the regulation "Navy standard;" or vice versa, as the case might be. In such tests a true comparison of the relative efficiency of the two paints could be determined.

The report of the American Society for Testing Materials, subcommittee No. 23 (1925), records the results with 11 vessels partially or completely covered with test paints, and in addition to these 7 have been examined in the course of this investigation.

From the data given in their report it can be seen that in most cases there was no noticeable difference in amount of fouling, although in almost every case the experimental paint film did not "hold up" as well as the "standard." These data indicate not only the ineffectiveness of poisons but also the very significant effect of the nature of the surface film in the matter of fouling, a subject that will be considered next.

SURFACE FILMS

Since the major importance of the problem of fouling of ships' bottoms centers about the question of frictional resistance of the surface of the ship in passing through the water, the nature of the film covering this surface is of prime importance. It has been recommended by many people that paints of a greasy character would be advantageous, on the theory that there is no adhesion between the films of oil and of water. However, McEntee (1915) maintains, from his experimental data, that the most favorable coating for ships' bottoms, as far as skin friction is concerned, is a paint that offers a permanent, hard, smooth surface.

From a biological point of view, as far as the attachment of larval forms causing fouling is concerned, the nature of the surface film also is of great importance. In the course of the examinations considered in this paper it was noted that fouling was most severe in regions where the surface was not smooth. Thus, in the areas where paint had peeled off, as shown in Figure 33 *A* the growth frequently was heavy, provided corrosion had caused a roughened surface. Frequently the number of barnacles that attached to a colony of Bryozoa (fig. 33 *B*), or even to other barnacles, would be much larger than on the adjoining smooth surface of the ship's hull. In other cases, where the pigment of the paint had not been mixed properly before applying, the resulting rough surface often was fouled more heavily than in regions where the paint offered a smooth surface. (Figs. 33 *C* and *D*.) These observations are confirmed by reference to the report of Adamson (1922), in which he presents data to show that the "problem [of fouling] covers physical properties as well as chemical properties of the paint film."

In the summer of 1922 Bray (1923) made some preliminary tests on the effects of various surfaces in relation to the attachment of barnacles. He set out two sets on separate racks at Beaufort, N. C.; but, he concludes, "unfortunately, the length of time the racks were exposed, due in part to the lack of material and to an accident which caused them to lose rack A, after nearly four weeks exposure, renders any attempt at anything but tentative conclusions of little value."

These tests included such surfaces as glass, beeswax, eseter gum, and shellac, with various types of poisons and combinations. He, however, concludes that "there seems little doubt that a film of a 'waxy' nature is capable of greater retention of the toxic agent than a thinner, harder film." This point is brought up at present, without reference to the question of poison, only to show the superior results obtained with "waxy" surfaces.

The writer has observed barnacles attach to metal surfaces of many sorts, provided no electrolysis was present, to wood, stone, tile, glass, rubber, and shells of more than 30 species of animals—in fact, to everything that is found submerged at

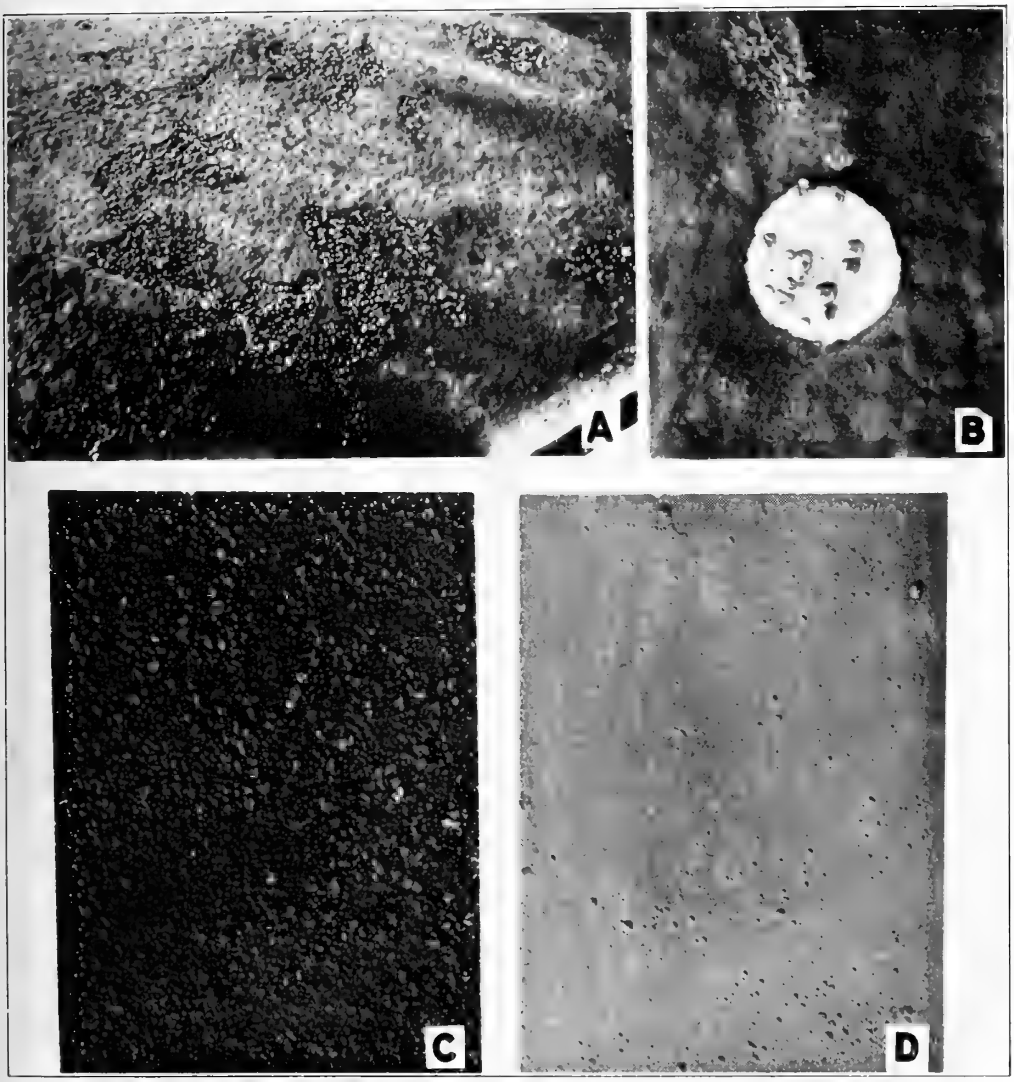


Fig. 33.—Effect of surface film on fouling. **A,** portion of the hull of the U. S. S. *New York* (Norfolk, Va., April 3, 1924), showing heavy set of barnacles where paint had peeled. **B,** also from the *New York*, showing attachment of barnacles on rough surface of a bryozoan colony. **C** and **D,** two test panels submerged at Beaufort, N. C., for identical periods of time, both with poisons but one (C) with a rough surface and the other (D) with a smooth surface

proper seasons and in favorable waters, with the exception of certain algæ. However, not all algæ are free from such attacks. Darwin records the occurrence of a special form of barnacles grown on the southern coast of Africa, and the author has found another variety growing in abundance on the fucus on the breakwater at Beaufort, N. C.

Nevertheless, the question of selective attachment of the larvæ of barnacles has proved a fascinating one for experimental work. Knowing that barnacles attach while in the cyprid stage, by means of an adhesive secretion thrown out from the tip of the antennæ, the possibility of finding some substances to which this "glue" would not adhere presented an interesting phase of the problem.

It has been found that the larvæ of certain barnacles (*Chelonibia testudinaria*) attach only to the backs of turtles; others (*Chelonibia patula*) to the shells of crabs; others (*Dichalaspis mülleri*), again, to the gills and in the gill chamber of certain species of crabs; and that one type of barnacle (*Balanus galeatus*) grows only on a special kind of coral. Likewise, other barnacles are found only *above* low tide line (*Balanus balanoides*), and others, again, only *below* low tide line (*Balanus crenatus*).

Considering these possible factors, and especially the relation of the adhesive substance of the barnacles to the nature of the surface to which it attaches, some experiments have been made, using more than 12 different compounds, including several decoctions made from different marine algæ and which show conclusively that no barnacle can attach to these films (at least within three weeks) during a heavy "setting" period, when all other surfaces were being coated with young barnacles.

It is also of interest in this connection that the presence of a slime film on the experimental panels, as well as on ships' bottoms, has been considered by some to be advantageous in preventing fouling, while others take the opposing view. Recent work done at the University of Washington by Miss Hillen (1923) would indicate that this slime is of bacterial composition, and she even maintains that "without this slime the barnacle would not settle upon the object (test panel) or develop upon it, as the slime is used as food material for the young barnacle in its first development." Further evidence on these points seems to be needed.

METALS

Different metals have been used as a means of preventing fouling since early times, as was described in the introduction to this paper. Copper and zinc were used abundantly on wooden ships, but with the adoption of steel vessels the use of these metals created electrolytic action that proved disastrous to the iron.

That copper has a protective function toward certain growths is seen from the record of the *Denver* (March 16, 1923), *Cleveland* (April 10, 1921), and the *Phalarope* (August 19, 1923), all of which are wooden ships that were partially or completely plated with copper sheathing. On these vessels barnacles were found as abundantly on the copper as elsewhere, but algæ and hydroids were conspicuously absent. Bryozoa and serpulids were present occasionally, but were not nearly so prevalent as on the propeller blades and the struts, which were of alloy composition, probably bronze. This difference was often noted on the propeller blades of iron ships, as on the *Florida* (March 15, 1923), where a very dense growth of hydroids covered the entire bottom but none were present on the propeller blades.

A complete study of the relation of various metals to fouling has been made recently by Parker (1924), who submerged panels of zinc, iron, aluminum, tin, lead, and copper. He found more or less fouling on all of them except the copper, and only a small amount on zinc. He explained this difference on the basis of ionization of these metals in salt water and the solubility of the resulting compounds. Thus, he states:

> The poisonous effects of these metals on marine animal life will depend upon the intrinsic toxicity of their ions, relatively high for all heavy metals, and the solubility of their hydroxides and basic carbonates in sea water. These solubilities in the case of Fe, Sn, and Al are in amounts inappreciable; in other words, these metals in sea water are not surrounded by a layer of poisonous ions, and hence animals may grow upon them. In the case of Zn and Cu, on the other hand, the corresponding compounds are appreciably soluble in sea water, and the poisons thus liberated prevent the growth of animals upon these metals.

His experiments with metal couples, however, have shown results that indicate a means of preventing fouling, even if an impractical method. He found that by coupling copper with metals higher in the electromotive series this metal can be rendered chemically inactive in sea water, and under such circumstances animals will grow freely upon it. Similar results were obtained with other couples, so that Parker concludes that "marine animals will grow upon any heavy metal, provided that metal does not liberate ions or soluble compounds." Conversely, it would accordingly be apparent that any electrolytic action causing ionization would serve to prevent fouling.

LIGHT AND COLORS

During the course of the examination of the second ship observed in dry dock it was observed, as previously noted in this report, that fouling was most severe in the region of the run and beneath the bilge keels of the ship. This increase in amount of fouling on lightly or moderately fouled ships in all areas that might be considered as "shaded" has been one of the most outstanding points noted during the whole investigation. More than 50 per cent of all examinations showed such results very strikingly. Other explanations have been offered to explain this intensification of growth in restricted areas, as, for example, the protection afforded in such locations. The writer, however, has held that the main factor was the influence of light. This contention no doubt was influenced greatly by previous knowledge of various biological studies on related phenomena.

The reaction to light of animals and plant organisms has long been a favorite study of biologists, because of the fact that most organisms react to this stimulus, as well as because of the ease with which the stimulating agent can be controlled. Lord Avesbury (Sir John Lubbock, 1904) was one of the first to demonstrate the fact that animals of many sorts react to light of different colors, finding, for example, that bees "prefer" blue flowers and that the tiny water fleas, Cladocera, gather in the region of the red if given a choice of all the colors of the spectrum.

More recently Mast (1911) and others have shown that reaction to light is a property common to almost all living things, both plant and animal. He showed, among other experiments, that the larvæ of one of the hydroids (Eudendrium) common on ships' bottoms react negatively to light, while the spores of certain plant forms (algæ), also common on ships' bottoms, are positive in their reaction to

light. More recently, Caswell Grave (1920 and 1923) and his students have shown that the larvæ of several tunicates (Amaroucium, Perophora, and Botryllus) are positive to light upon liberation from the mantle chamber of the adult, but at the time of attachment all are definitely negative to light. Thus Grave and Woodward found for Botryllus (a tunicate common on our North Atlantic coast) that the free-swimming period for these larvæ persisted for from 1 to 27 hours, and that during this time they react positively to light for a "comparatively long period," and then are indifferent or nonresponsive and finally negative to light for a "period of short duration just before metamorphosis begins."

Some work has been done on the reactions of the barnacle larvæ to light, notably by Jacques Loeb (Groom and Loeb, 1890); but this work was done only on the early larval stages (nauplii) and consequently has little bearing on the problem, as the cyprid stage is the condition in which the barnacles attach to ships' bottoms. In his studies of the "nauplean larvæ" it was found that they were usually positive to light upon liberation from the parent, but that reversal of reaction frequently occurred, probably dependent on environmental factors.

That practical tests have been made on ships' bottoms regarding the effect of colors is recorded by Holzapfel (1923), who concludes that the advantageous effect, if any, is too slight to warrant any serious consideration. However, the report of Captain Macauley (1923) would indicate that not all nautical men would so minimize its practical importance.

As this problem (the effect of light on fouling) seemed one that offered considerable possibilities, and inasmuch as no controlled experimental data were available regarding it, considerable time has been spent on its study. This work has been of four kinds. First, the use of steel plates coated with variously colored paints, submerged in a tidal channel whose waters were heavily infested with fouling organisms; second, the study of the effect of a submerged electric light on the attachment of organisms (the results of this experiment were so inconclusive, due to various difficulties, that they are not presented here); third, the use of colored tiles under similar conditions in order to eliminate the possible effect of the constituents of the paint film, leaving only the effect of light; fourth, laboratory studies of the reactions of the cyprid larvæ of various species of barnacles to light of known intensity and spectral distribution; and finally, as a corollary of this, the study of the actual process of attachment and the effect of light at the time of attachment.

SUBMERGED TEST PANELS

Attachment of fouling growths on steel panels painted with materials of different colors has been studied by several workers. Soon after beginning this investigation a conference of men working on the various aspects of the problem of fouling of ships' bottoms was held at Beaufort, N. C., on October 25, 1922, where large numbers of panels had been submerged to test the effectiveness of as many different paints. Already at this time a series of panels painted with different colored paints had been submerged at the suggestion of H. A. Gardner. As he states in his circular (1922) recording the fact that these were submerged, but without recording any results, these were submerged "to determine the effect of colors upon attachment of barnacles. It is believed that the barnacles might seek, through protective colora-

69861—28——4

tion, certain colors and avoid other colors against which they might present a more obvious appearance." However, at the time of the first examination by the author these plates showed results that were quite inexplicable on the basis of adaptive coloration but proved sufficiently interesting from a biological viewpoint so that a preliminary report by the author was submitted at that time (December, 1922), from which the following paragraphs are quoted:

In order to test this hypothesis a series of 12 steel panels had been exposed. All were painted with two coats of standard anticorrosive paint and a third coat which contained the desired pigment. All of the pigments, as well as the paint mixtures used, were nontoxic. (See H. A. Gardner, 1922.) All plates were exposed on the same day, and each panel was suspended separately from a rack built in a tidal channel, where the water flows at between 4 and 6 miles per hour whenever the tide is running. They were submerged in water about 6 feet deep, being held in a vertical position about 12 inches from the bottom. They were arranged in a row, end to end, about 2 or 3 feet from each other and parallel to the water currents in the channel. The plates extended in a line approximately north and south. Both sides of each plate, consequently, received about the same amount of light during the course of the day. Examination was made about two months later. As all of the plates had been treated alike, except for the colored pigments, and as all factors influencing them were the same, it may be concluded that any difference in the amount and nature of the fouling would be dependent on color.

The results obtained are presented in a table (No. 8) and may also be seen in the photographs. (Fig. 34.) The colors of the plates shown in the photographs are as follows: 201, white; 202, yellow; 203, red; 204, green; 205, blue; and 206, black. By referring to the photographs and to the table it will be seen that there was much more fouling on the dark plates than on the lighter colored plates. The contrast between the white and black plates was very marked.

TABLE 8.—*Organisms found on test panels that differed in color of paint*

Color of paint	Clean area	Algæ	Worm tubes	Bryozoa	Hydroids ("grass")	Barnacles
White (201)	Extensive (65 per cent).	Abundant	Very few	0	0	0.
Yellow (202)	Extensive (40 per cent).	Very scattered	Abundant	0	0	0.
Red (203)	Few and small (5 per cent.)	do	Many	Very numerous.	Few	Very few.
Green (204)	Extensive	do	do	Numerous	0	Few.
Blue (205)	Few, medium (15 per cent.)	do	do	do	0	Fairly numerous.
Black (206)	None	(?)	Few (?)	do	Many	Very abundant.

It will be noted that the clean areas were most extensive on the white (65 per cent) and yellow (40 per cent) plates. The growth of very fine algæ was present only on the lighter colored plates and was abundant only on the white plates. It formed almost the only growth present on these plates.

The worm tubes (irregular, slender, white formations seen in the photographs), formed by an annelid worm of the genus Hydroides, appeared very numerous on all the plates except the white and black. The latter may have had as many worm tubes as any other plate, but because it was so densely covered by other growths the appearance of any tubes was obscured.

The Bryozoa (characteristic circular patches seen in the photographs) were noticeably most abundant on the red plates, although all others, except the white and yellow, were also heavily infested. Not a single specimen was found on the white and but a few on the yellow plates.

The hydroids (grass) were absent from all but the red, blue, and black plates, and were abundant only on the last.

The barnacles were the most striking in their distribution. Only on the blue and black plates were many of them found, and they were most abundant on the black.

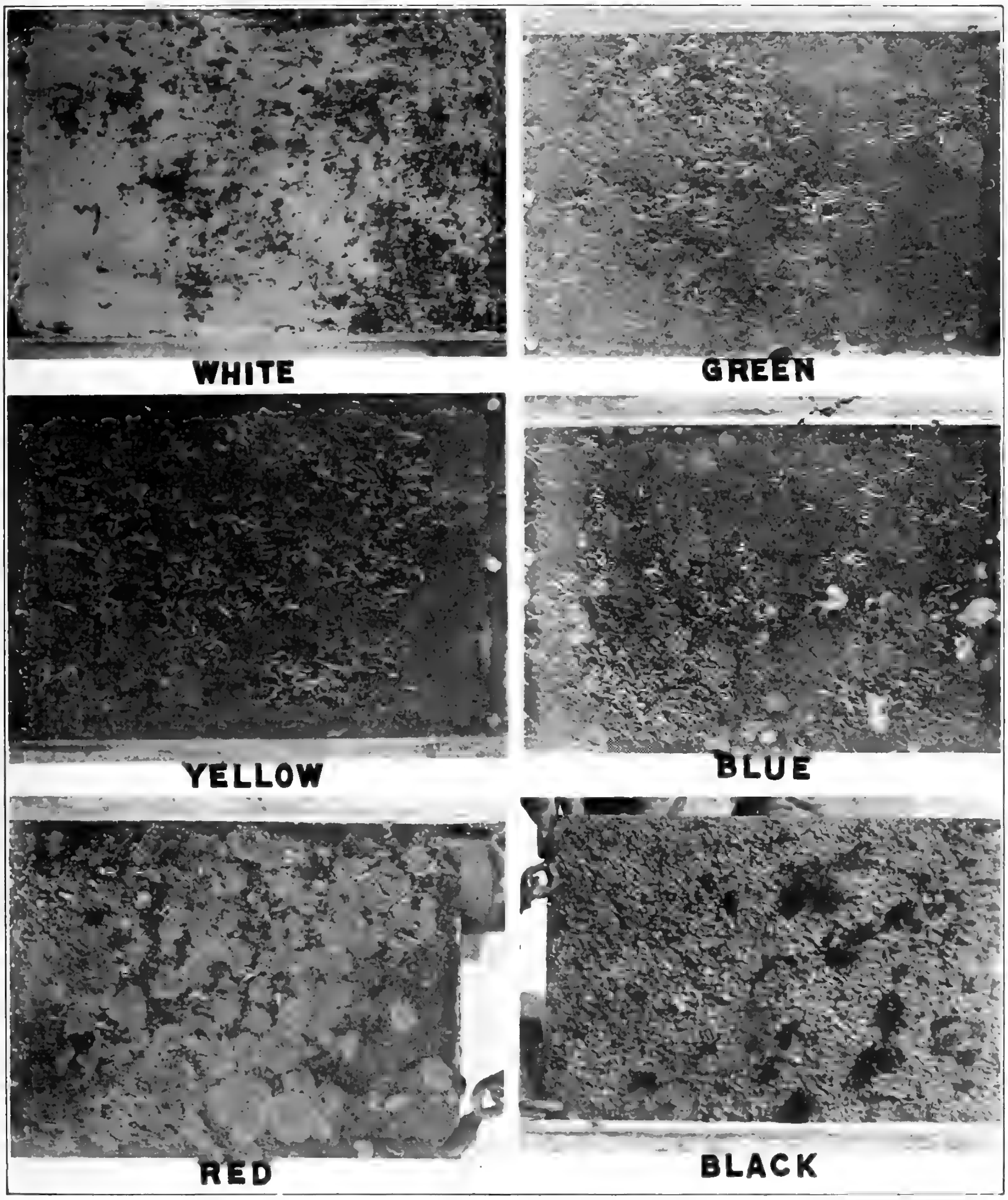


FIG. 34.—Relation of color to amount of fouling. For description see p. 240 of text. Variously colored plates submerged at Beaufort, N. C., for 2½ months, August to October, 1922

It can be seen clearly then that there is a very definite relation between the color of the plates and the kind and amounts of growths on each. The barnacles and hydroids apparently attach only to dark-colored surfaces, while Bryozoa and worms attach to somewhat lighter surfaces as well, but apparently prefer the red and yellow, respectively.

Since the white barnacles were found most abundantly on the black plates, and since neither the barnacles nor the worm tubes, both of which are conspicuously white, were found on the white plates, it would seem that there is no evidence of protective coloration.

The apparent selection of the darker surfaces can best be accounted for by a study of the behavior of the larvæ of these organisms. The newly hatched larvæ of almost all sessile marine animals (as well as many others) react positively to light; that is, they swim toward the source of light. This period of positive reaction, however, is of only limited duration. (It appears to be only long enough to carry the young organism to the surface of the water, there to be carried about and distributed by the ocean currents.) Most of these larvæ then become negative to light. It is in this period that they attach and molt into sessile organisms with characters similar to those found in the adult. This fact has been demonstrated experimentally for certain hydroids, annelids, and tunicates. It is also known that lights of different wave lengths have different effects on various organisms. Some go toward red, others toward blue, green, etc., depending on their relative stimulating efficiency on the specific organism.

On this hypothesis one can readily explain the results found on the plates described above. It would seem (from the limited evidence at hand) that barnacles are strongly negative to light at the time of attachment. Hydroids (grass) are likewise so. The Bryozoa, although negative to white light, are apparently "attracted" especially by the red, and the worms (Hydroides) apparently by the yellow-red light waves. It would appear that this selection or "tropism," holds good for the animal forms only, as the algæ were found extensively on the white plates.

As this hypothesis is in accord with observations made on ships' bottoms, where one finds the densest growths in regions least exposed to light, it seems safe to conclude that most organisms commonly found attached to the bottoms of ships become attached there because of a relative decrease in the amount of light given off by such areas.

It was realized that these notes and tentative conclusions were based on very limited evidence, and it was hoped that this problem might be investigated more thoroughly by experiments in which many of the unknown factors would be more definitely controlled. Sources of error in the above experiments were numerous, although probably more or less equal for all. The relative amount of light, the amount reflected from other plates of different colors and composition in the immediate vicinity, are all unknown factors that should be eliminated in future tests. The behavior of pelagic larvæ of different ages was not known for any of the species commonly found on ships' bottoms. It was believed, accordingly, that such studies, with controlled factors, would be of value both from an economic and a purely scientific viewpoint, and a few were carried out subsequently, as described in the following pages.

Although several successive series of panels were submerged, not all presented as clear-cut results as did the series recorded. This lack of differentation was especially noticeable after the plates had been exposed for several months (if in spring or summer months), which, no doubt, can be explained by the fact that once the plate is heavily coated, colors lose their influence, and, consequently, within a relatively short period during the season of the year when fouling is most severe, all of the plates become very heavily fouled, regardless of color. However, as less than 10 per cent of all active vessels become heavily fouled, and those that become moderately foul do so, as a rule, only after a considerable period out of dry dock, it will be realized that under practical conditions the relative influence of colors will be greatly prolonged.

A similar series of panels was exposed in the following summer (1923) at Woods Hole, Mass. (fig. 35), with the results shown in Table 9 in which is shown their relative efficiency on the basis of the area free from fouling. All films were in excellent condition. No corrosion was evident anywhere. Fouling was caused largely by Bugula, with some Alga and a small amount of Obelia. Although no barnacles attached during this period of the year, the same relative differences in amount of fouling are seen here as in the plates at Beaufort.

TABLE 9.—*Results of plates exposed at Woods Hole, Mass., submerged on May 31, examined July 25, 1923, painted with two coats each of the "photographic" color paints, as prepared by Henry A. Gardner*

No.	Plate color	Film	Fouling	Percentage of surface not fouled
8	Black	Good	Heavy	10
7	Dark green	do	do	20
4	Red	do	do	20
5	Chocolate	do	do	20
3	Yellow	do	Medium	30
1	White	do	do	50
6	Light green	do	do	60
2	White	do	Slight	90

It was soon realized, however, that these results were open to various explanations, for the material employed to produce a given color was different in each case, and this factor alone might account for the differences in fouling. Accordingly, other methods of attack on this question were planned. These included, first, a submerged electric light with colored panels on each side; second, a set of colored tiles; and, third, a series of experiments in which the active cyprid larvæ were exposed in the laboratory to light of known wave length and intensity.

SUBMERGED COLORED TILES

Woods Hole, Mass.—During the summer of 1923 a series of colored tiles, with both glazed and unglazed surfaces, were submerged by the author at the biological station of the United States Bureau of Fisheries at Woods Hole, Mass. Tiles were used in these experiments to eliminate all possible effects of any toxic action that might have resulted from the use of pigments needed as coloring matter in the paints employed in the previous experiments with panels. These tiles were submerged in two sets of panels—eight glazed in one panel and five unglazed in the other. The regulation size was 6 by 6 inches, but a few were half size, measuring 3 by 6 inches, and about one-half inch in thickness.

These tiles were submerged on May 13, 1923, and were examined from time to time until July 25. The amount of fouling was noticeably less on the lighter-colored plates. However, there were several apparent inconsistencies, the glazed, black tile having less fouling than any of the others, excepting the two white tiles, whereas the unglazed, black tile was the most heavily fouled. However, the following gradation, from least to most, was noticeable in amount of fouling:

(*a*) Glazed set: White, black, light green, yellow, pink, blue, green, red, and dark green.

(*b*) Unglazed set: White, yellow, red, dark green, and black.

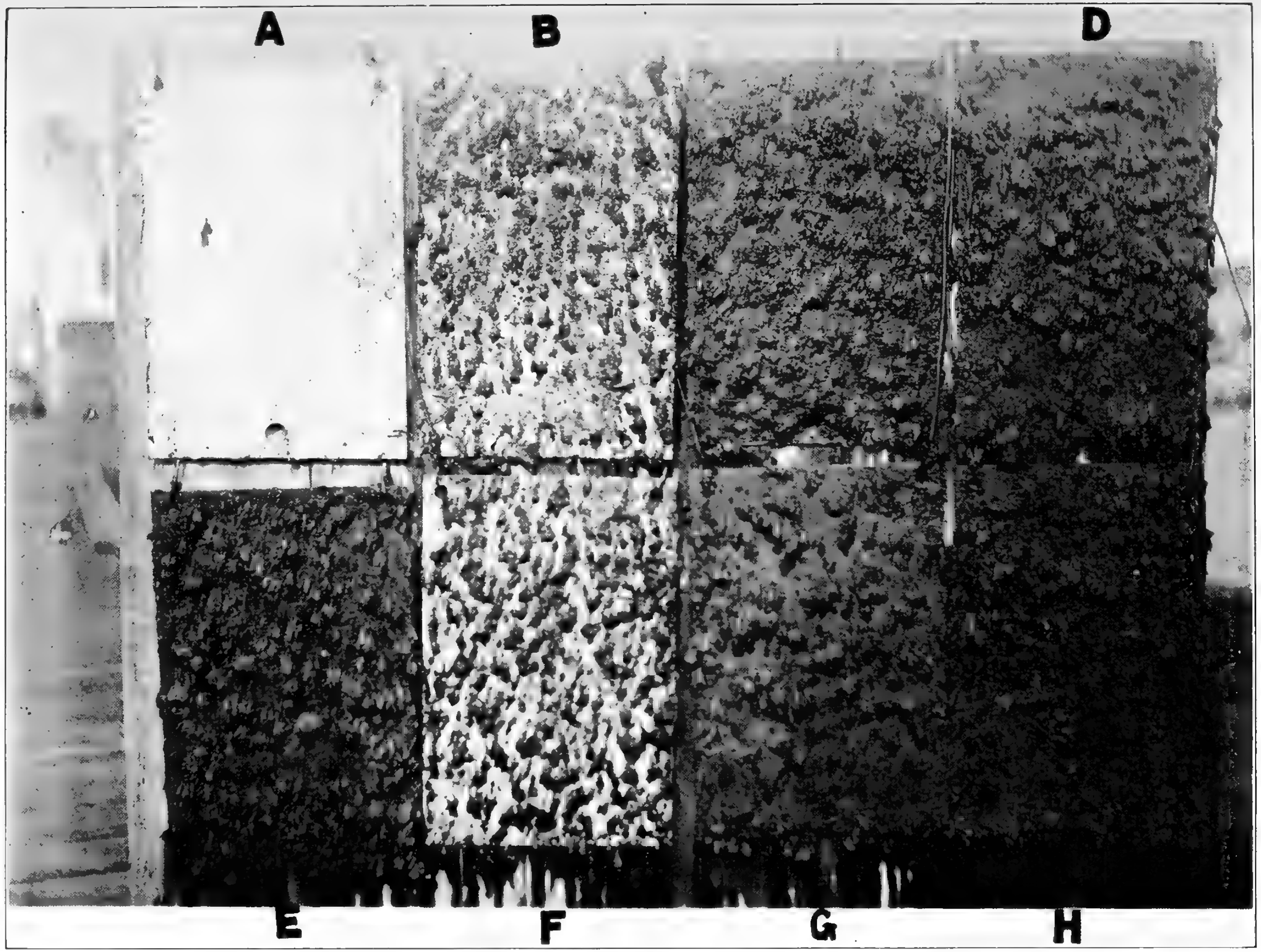


FIG. 35.—Relation of color to amount of fouling. Panels painted with nontoxic paints and submerged from August 4 to September 16, 1923, at Woods Hole, Mass. Growths almost wholly of Bryozoa. **A,** white (ZnO); **B,** yellow; **C,** light green; **D,** chocolate; **E,** black; **F,** white (titanox); **G,** dark green; **H,** red

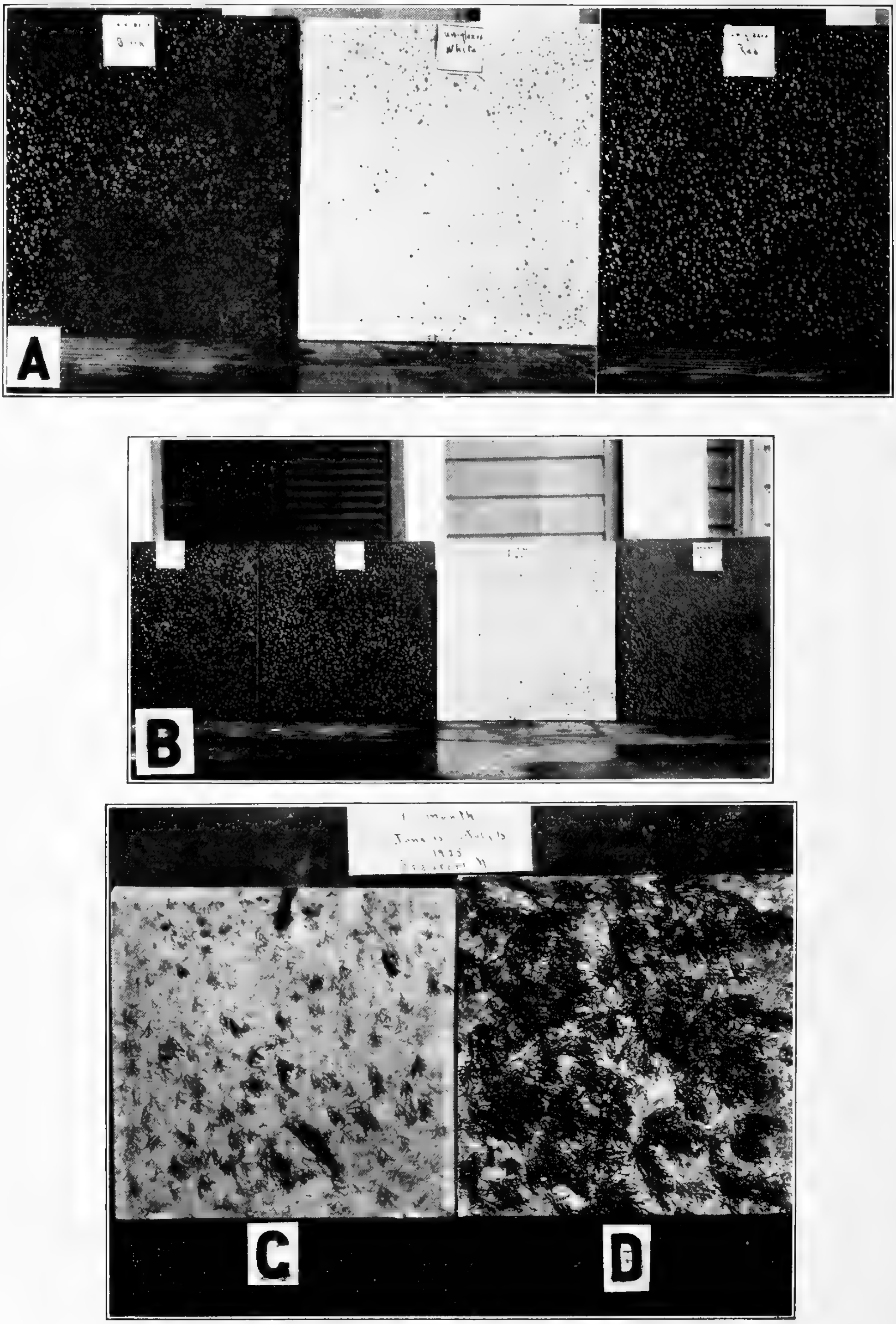


Fig. 36.—Relation between color and fouling, as judged by numbers of barnacles and Bryozoa that attached on colored tiles. **A,** unglazed tiles submerged for one week (July 28 to August 3) at Beaufort, N. C. **B,** another series of unglazed tiles (black, red, white, and green) exposed for 8 days. **C** and **D,** white and black unglazed tiles exposed for 1 month, showing relative amounts of fouling due to Bryozoa (Bugula)

It was noticed that the growths were mostly Bryozoa, with a few hydroids, no barnacles attaching at Woods Hole at this season of the year. As the latter forms are of the greatest significance in the matter of fouling, these tiles were used for tests at Beaufort during the following season, where the summer set of barnacles is very heavy.

Beaufort, N. C.—During the summers of 1924 and 1925 several sets of four or five unglazed tiles were submerged at the Fisheries biological station in a tidal channel, at a uniform distance (about 3 feet) below low water. Unglazed tiles were selected for these experiments, because it had been found that glazed tiles gave conflicting results, because of their "mirror surface" or the reflecting power of such surfaces, as described below. Careful counts of all barnacles that attached, or calculations of the total, based upon accurate counts of several limited areas, were made of all the barnacles attached on each plate during the experiment. These results are given in Table 10.

TABLE 10.—*Number of barnacles that attached daily, one month, on unglazed tiles of different colors at Beaufort, N. C.*

Date, 1925	Total number attached				
	White	Buff	Dark green	Red	Black
June 18	237	570	700	2,840	720
June 19	520	864	572	1,900	884
June 20	680	1,120	1,032	1,800	2,108
June 21	712	1,587	2,068	1,344	2,760
June 22 to 24 [1]					
June 25	128	251	224	240	199
June 26	429	442	809	584	961
June 27 [1]					
June 28	1,164	1,757	1,836	1,491	1,800
June 29	166	760	1,116	916	944
June 30	230	1,040	1,381	1,168	1,900
July 1	750	1,100	1,500	1,800	2,200
July 2	1,400	2,000	2,700	3,000	2,500
July 3	1,800	1,600	2,500	1,800	500
July 4 and 5 [1]					
July 6	1,500	1,900	1,800	1,500	1,700
July 7	280	430	500	564	379
July 8	263	1,130	1,200	1,500	458
July 9	400	713	470	591	520
July 10 to 15 [1]					
July 16	122	212	262	252	300
July 17	40	224	300	448	316
July 18	53	173	180	176	196
Total, 19 days	9,864	18,872	21,150	23,914	21,345
Daily average	419	993	1,113	1,259	1,123

[1] Omitted.

It is evident from this table, which shows the average results of all tests, that the darker the surface the more barnacles are found attached. These results may be seen even more clearly in Figure 36. While a light surface is by no means a cure-all, it will be realized that anything that reduces the fouling 50 per cent is a very important factor. Especially is this true when one realizes that on less than 5 per cent of the ships (on the basis of an examination of 250 vessels) may one find a growth of barnacles at all comparable in number to those obtained at Beaufort in less than one week.

Glazed tiles also were used by the author, but conflicting results were obtained, similar to those recorded in the memorandum report by Perry and Bray of August,

1923. That these results are not valid, because of the varying amounts of light reflected, depending upon the position of the sun and brightness of the day, can be seen easily by referring to Figure 37, which shows photographs of these glazed tiles, taken in front of a south window in bright but diffused light (not direct sunlight).

It will be noticed at once that, optically, there is little difference, under these conditions, between the amount of light reflected from a white or a black surface, as seen in Figure 37, *A* and *B*, and even red is optically almost as "light" as white under these conditions. It is thus evident that any experiments based upon the use of such tiles are of little value in judging the effect of relative light intensities. Accordingly data from unglazed tiles only have been considered of value in these experiments.

REACTIONS OF THE CYPRID LARVÆ OF BARNACLES TO SPECTRAL COLORS

The reactions of the cyprid larvæ of two types of barnacles that cause fouling (*Balanus amphitrite* and *B. improvisus*) were tested by exposure to monochromatic light of known intensity. Light filters were selected that possessed a narrow transmission band and were of known composition and thickness. In Table 11 is given a list of all the filters used, with the limits of light transmissions and the dominant wave length of each filter. A copper sulphate filter was used to cut out the infrared light waves.

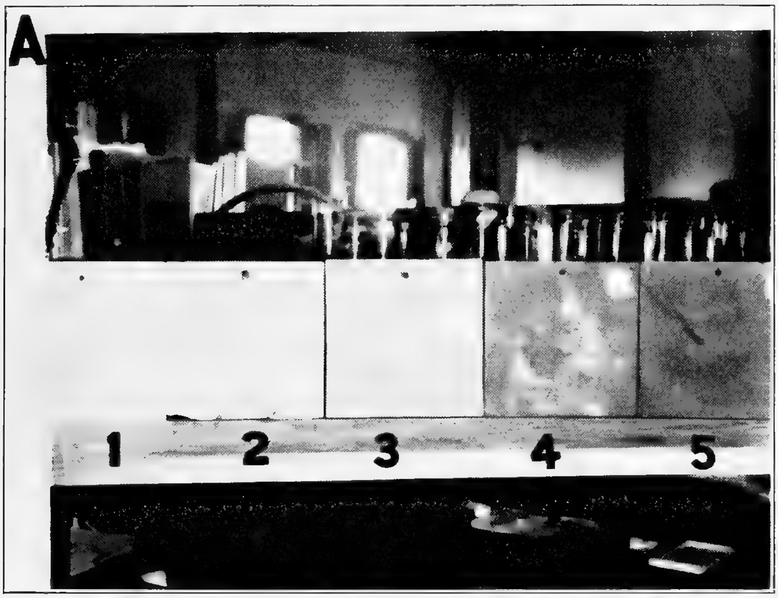
TABLE 11.—*List of filters used in experiments on reactions of the cyprid larvæ of barnacles to spectral colors, showing total spectral transmission and dominant wave lengths*

[The letter "C" after a filter denotes a Corning glass filter. The numbers after the Corning glasses refer to the transmission curves shown in Bureau of Standards Technological Paper No. 148. The letter "W" denotes a Wratten filter, and the number refers to the transmission curves found in the booklet "Wratten Filters," published by the Eastman Kodak Co.]

Filter	Total transmission	Dominant wave length	Filter	Total transmission	Dominant wave length
		Mu-mu			*Mu-mu*
Ultra, C 83	315–428 mu-mu and 609 red end.	355	Blue-green, C 56	340–700 mu-mu	505
			Green, C 52	425–670 mu-mu	530
Purple, C 69	310–485 mu-mu and 690 red end.	370	Green, W 58	485–635 mu-mu	540
			Yellow, W 15	500–700 mu-mu	590
Purple, W 35	300–475 and 650–700 mu-mu	420	Orange, W 22	545–700 mu-mu	620
Blue, W 49	400–510 mu-mu	440	Orange, C 38	540 red end	640
Blue, C 60	335–640 mu-mu	460	Red, C 19	620 red end	700
Blue, C 59	335–690 mu-mu	480			

In order to separate the effect of color from that of intensity it was necessary to determine the total amount of light energy transmitted by each filter. The calibration of these filters was very kindly done by the United States Bureau of Standards. By use of this information the total light energy transmitted through one filter could be balanced by that transmitted through any other filter by moving the source of illumination. By using two beams of light at right angles to each other, and each of equal intensity, the relative effects on large numbers of cyprids were determined for all the filters.

The results of these experiments are summarized in Figure 38, which clearly indicates a great difference in the stimulating efficiency of various spectral colors. In the region of the spectrum between 500 and 600 mu-mu, or from light blue to



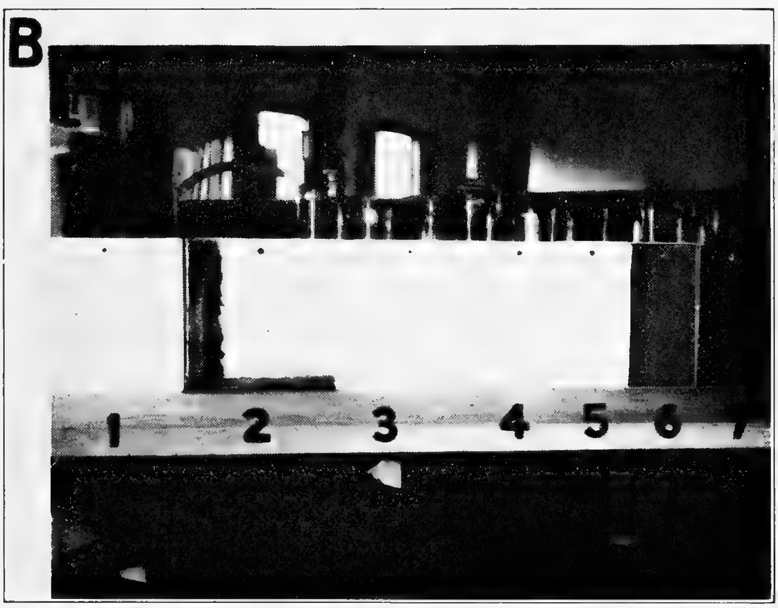


Fig. 37.—Optical effects of glazed tiles, demonstrating their uselessness for these tests. **A.** 1 glazed white; 2, glazed black; 3, unglazed white; 4, unglazed red; 5, unglazed black. **B.** Al glazed tiles. 1, white; 2, black; 3, pink; 4, yellow; 5. light green; 6, dark green; 7, red

yellow, the stimulating efficiency is equal to more than 50 per cent that of white light; while between 530 and 545 mu-mu it is more than 90 per cent, or virtually

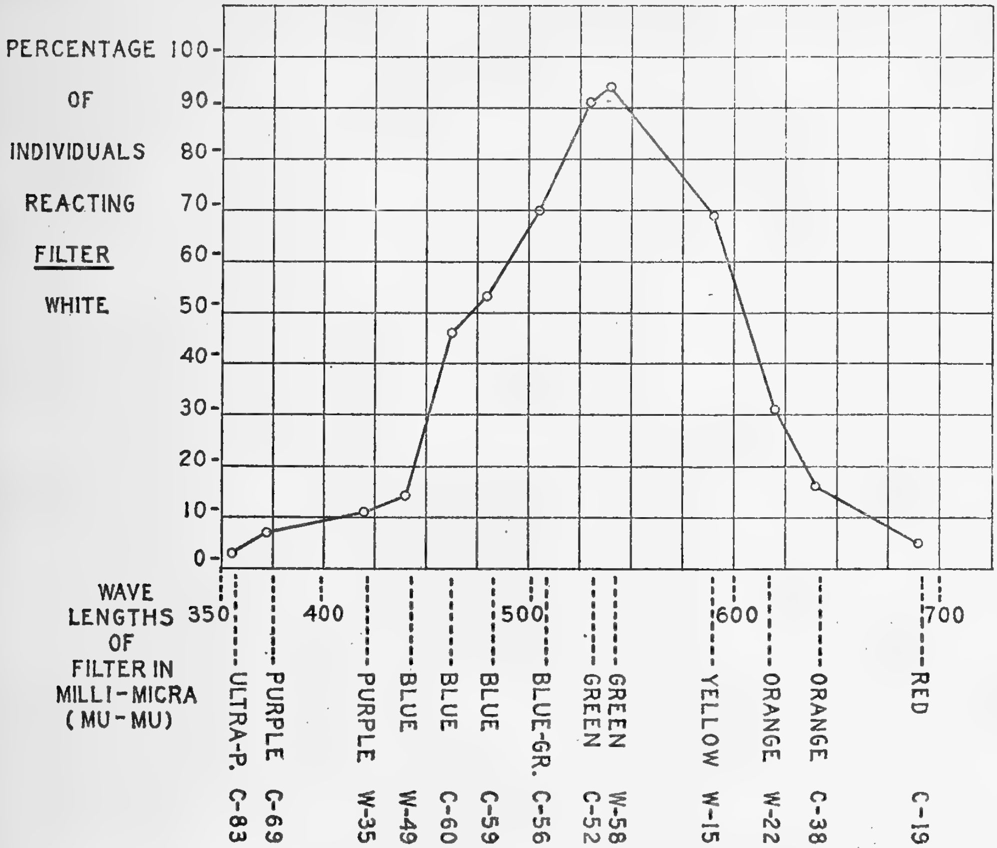


FIG. 38.—Distribution of the stimulating efficiency of equal energy values among the various parts of the spectrum for the cyprid larvæ of certain barnacles

equivalent to white light. On the other hand, light of wave lengths of 700 mu-mu has less than 5 per cent of the efficiency of white light, and likewise at 420 mu-mu

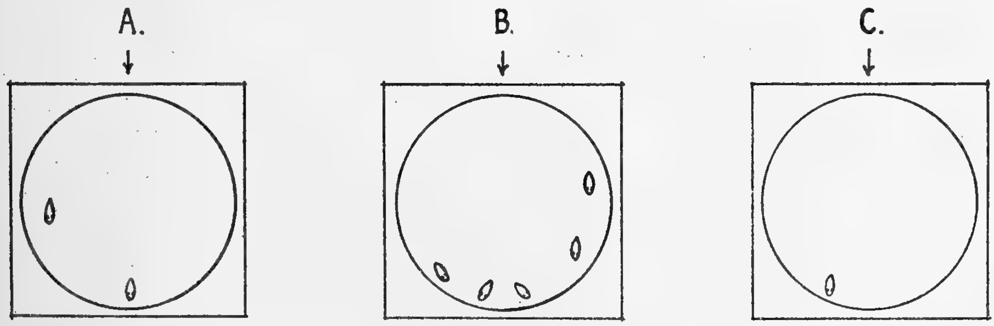


FIG. 39.—Attachment of barnacle larvæ with reference to source of illumination (indicated by arrows)

the stimulating efficiency is very much reduced. For a more complete account of these experiments see Visscher and Luce (1928).

It is evident, therefore, that light rays in the field of blue-green have a much greater effect in activating the cyprid larvæ of barnacles than the light rays in other fields of the visible spectrum.

REACTIONS OF LARVAL BARNACLES TO LIGHT AT TIME OF ATTACHMENT

It has been demonstrated that the larval barnacles are sensitive to light and respond more vigorously to light in the blue-green portion of the spectrum than to light of other color. That these organisms are negative to light at the time of attachment was demonstrated by isolating a number of the cyprids and placing them in small cubical aquaria, which were then covered with black paper on five of their six sides. The uncovered side was exposed to light from a north window.

The results of these experiments, which were repeated on several occasions, can be seen in Figure 39. It will be noted that in each dish the cyprids attached in that half of the container away from the source of light, and that in each case the individuals were so oriented as to be directed away from the source of illumination.

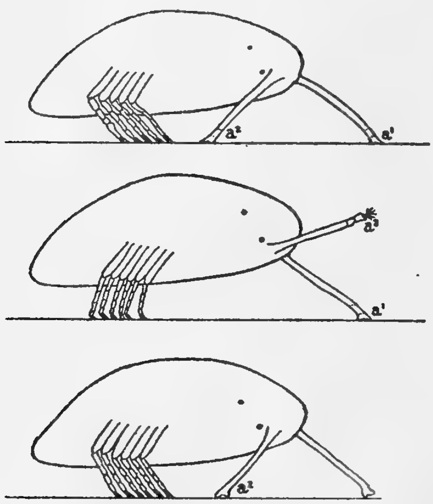


FIG. 40.—Successive movements of a cyprid barnacle larva at the time of "selecting" a place of attachment

It can be seen clearly from these experiments that for the two types of barnacles that were tested, light is an important factor in determining the point of attachment, and that they orient themselves with their anterior ends directed away from the source of light.

It would appear evident from the results of the submerged colored panels, from the submerged tiles, from the experimental data on reaction of cyprid larvæ to spectral color, and, finally, from the above experiment, in which it is shown that cyprid larvæ become negative to light at the time of attachment, that paints varying from a light blue to yellow would accumulate the least amount of fouling, and that a light green paint probably would be the most efficient, all other factors being equal.

Process of attachment of the larvæ of barnacles.—After a free-swimming period of from three days to several weeks, the cyprids attach to some substratum and metamorphose into the adult type of barnacle. When the internal physiological conditions necessary for attachment are present, apparently correlated with the "lipoid" content of the organism, the larvæ have been observed, on many occasions, to "walk" on the substratum, apparently hunting a place for attachment. This remarkable performance is accomplished by alternate attachment and release of the adhesive tips of the antennæ, combined with the relaxation and contraction of the set of appendages, which result in giving the organism a forward movement. (Fig. 40.) In this manner these organisms have been observed to "walk" for considerable distances, and have been seen to "test" various areas for a period of more than an hour before finally attaching.

On several occasions the writer has been fortunate in seeing the actual process of metamorphosis while observing through a microscope. It was observed that after attachment by means of the antennæ the organism would "kick" vigorously for some time, but without effecting release. The animal then appeared to become fixed and metamorphosis followed. The two-valved shell of the cyprid stage was thrown off, as was also the exoskeleton of the appendages and usually the paired eyes as well. From this almost amorphous mass, the young barnacle soon emerges. A secretion continues to be laid down on the formerly ventral surface. and the rudiments of a coating (the future shell) appear around the sides of the mass. Whereas, when attached, the appendages extend downward, they now extend upward, and the mouth parts also have changed their position. A more complete account of this process and related phenomena is given by the author (Visscher, 1928).

It is thus apparent that barnacle larvæ "test" the surface to which they attach, and at no time do the bodies of these organisms come into direct contact with the surface to which they attach.

DISCUSSION AND CONCLUSIONS

From the data presented in this report it is apparent that fouling occurs almost entirely when ships are in port. For this reason passenger ships were found to be almost free from fouling, while ships temporarily out of commission, and battleships, were consistently the most severely fouled. It is accordingly apparent that vessels should be held in port as short a time as possible.

Fouling growths usually are killed if the vessels move from one port to another at a considerable distance. This is due, no doubt, to the differences in temperature, salinity, and dissolved salts of various kinds. However, the death of the organism does not necessarily free the ship from its fouling. Only the living portions are killed and the shells often remain for many months. If, on the other hand, a vessel moves into another port while the fouling growths are still young and succulent, such growths probably die and fall off completely, thus ridding the vessel of all fouling matter.

Fresh water also has been shown to cause the death of most organisms that produce fouling. However, the same results are found here as above; namely, that if heavy calcareous shells have already formed, the fresh water merely stops increase in growth but does not remove most of the material already there, unless it is very young and its parts are still soft.

Metal has been shown to remain free from fouling growths as long as electrolysis takes place and its ions are liberated. As this occurs normally, in sea water, for copper, this material will not foul heavily with most types of organisms unless such ionization is inhibited. It is evident, then, that to be effective it must be in such a condition that it will be wasting away continually, going into solution.

The efficacy of poison paints has been questioned because of biological considerations relating to the activities of the larvæ at time of attachment. It has been shown that the only time when a poison carried in a paint film can be effective is at the time of attachment of the fouling material. Immediately after this a film of calcareous or allied material is deposited by the organism and separates its tissues from the paint. Many vessels and experimental plates have been observed that had become

foul within 30 days from the time of painting with an antifouling composition. This would indicate the relative ineffectiveness of such material after a very short period. Much more important is the nature of the surface film in its relation to the method used for attaching the larvæ of the organisms that cause fouling. The beneficial effects of the paints now used very probably can be attributed far more to the nature of the surface (when in water) than to any peculiarly poisonous property that they may possess. It seems probable that undue emphasis has been placed upon the use of poisons in paints on steel ships, which is probably a hold over from their use on wooden vessels, and that the proper nature of the surface film is the desired goal.

Finally, this report presents data that demonstrate clearly the relation between light and the attachment of fouling organisms. The experiments with submerged panels of different colors, with submerged colored tiles, and with the cyprid larvæ exposed to equal energies of spectral colors, all show that barnacles are more sensitive to light colors than to dark, and that at the time of attachment they react away from this stimulus. Inasmuch as red is optically almost as dark as black, it is evident that a worse color could hardly have been selected. Yet red and brown are the colors of more than 90 per cent of the commercial antifouling paints used for steel ships. It is admitted that the red iron oxide so universally used makes an ideally inert "body" for such paints, but if a substance of a lighter color could be found as an adequate substitute, it seems very probable that its use would be advantageous.

SUMMARY

1. The fouling found on ships' bottoms is composed of both plant and animal organisms, with the latter the more important group wherever fouling is at all extensive.

2. Barnacles, hydroids, algæ, tunicates, Bryozoa, mullusks, and Protozoa are all found abundantly and in frequency and abundance usually in the order named.

3. Fouling organisms are almost exclusively those commonly found on rocks and other submerged structures near shore, especially in harbors.

4. Fouling occurs almost entirely while vessels are in port.

5. Passenger ships with regular schedules that permit them to remain for only very brief periods in port are the least foul of any group of vessels.

6. Most ships are moderately fouled after six to eight months from the date of dry docking.

7. Heavily fouled ships frequently carry more than 100 tons of fouling materials and occasionally more than 300 tons.

8. It is conservatively estimated that the annual cost of fouling to the shipping industry of our country is in excess of $100,000,000 per year.

9. Under optimum conditions vessels foul within 30 days of the time of dry docking and the application of poisonous antifouling paints, indicating the hypothetical value of antifouling paints.

10. The time that elapses between dry-docking periods is of great significance, but the use made of this time, whether in cruising or in port, is of even greater importance, for fouling is proportionally more severe as the length of time since previous dry docking is increased, but it is decreasingly heavy in proportion to the time spent cruising.

11. Vessels that are never in port for more than a few days at a time, and whose next port of call is at a considerable distance, rarely if ever accumulate much fouling.

12. Each vessel shows at the time of dry docking the visible record of its cruise by the diverse types of organisms found on her hull.

13. Fresh water kills most of the organisms that cause fouling within 72 hours, but if calcareous or chitinous growths already have been formed, such materials remain and the resistance is not materially lessened.

14. Certain species of barnacles grow at a very rapid rate, attaining a size of 2 inches and becoming sexually mature within 60 days.

15. Fouling can be predicted from a knowledge of seasonal abundance of larval organisms in given ports.

16. Certain barnacles are found attached on certain substances and in limited regions, indicating a relation between attachment and the nature of the surface.

17. Light has been found to be an important factor governing the attachment of the larvæ of the forms that cause fouling.

18. At the time of attachment the larvæ of *Balanus improvisus* and *B. amphitrite* are negative to light. (Most of the forms found on ships' bottoms probably are of a similar nature.)

19. Light in the field of green and blue has been demonstrated to have the maximum stimulating efficiency for the cyprid larvæ of several barnacles.

20. This report indicates the value of an intensive study of seasonal periodicity of fouling organisms, of the relation between fouling organisms at the time of attachment and surface films, and a study of properly prepared paints of lighter colors than those now in general use.

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PRODUCTION AND DISTRIBUTION OF COD EGGS IN MASSACHUSETTS BAY IN 1924 AND 1925

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CONTENTS

INTRODUCTION

PELAGIC EGGS AND LARVÆ

With very few exceptions all marine animals, and in fact almost all plants of the sea as well, spend a large part of their lives in the surface waters. Some forms remain pelagic a very short time, while others drift about for months. The fate of even the invertebrate communities inhabiting our coastal waters lies solely in the success or failure of their pelagic young to maintain themselves in the plankton. There must be ample food available, and the winds and tides must remain favorable at least until they reach the stage when benthonic life begins.

In regions where a definite drift flows constantly in one direction the communities would soon become exhausted were there not a constant supply of individuals from other sources. The fact that some groups of benthonic animals are not found in certain regions does not imply necessarily that conditions there are unfavorable for their growth. It is likely that currents would carry the young away before they could attach and the neighboring communities are not situated in such a way that they can serve as sources of supply.

In protected areas where no dominant drift occurs it is possible that young pelagic forms oscillate back and forth on the rising and falling tides, later descending to the bottom in approximately the same place from whence they originated. However, if we exclude such exceptional cases as inclosed bays and harbors, it is highly improbable that a single one of the individuals seeking the bottom along our coast succeeds in locating itself within miles of its point of origin.

The importance of drifts in governing animal distribution is by no means confined to invertebrate bottom forms. The relative importance of fish-spawning grounds as production centers is to a large degree dependent upon ocean currents. When one considers that for weeks and even months the helpless eggs and fry drift about at the mercy of the winds and tides, battered by storms and surrounded by enemies, it is not surprising that so small a percentage ever lives to reach maturity. Bigelow (1926, p. 69), in discussing drifts, states: "Outside the outer headlands, however, the journeyings of floating fish eggs are, generally speaking, so considerable that they are often measured better by degrees of latitude and longitude than by miles." Off the northern coast of Norway, Hjort (1914) found that young cod fry sometimes were carried for hundreds of miles. He also found that the actual quantity of eggs produced often is not in itself a factor sufficient to determine the numerical value of a year class. A rich spawning year may yield a very disappointing year class, while a large year class may have its origin in a very poor spawning year. This has been observed repeatedly in Lofoten.

However, it has also been found that the abundance of any age group probably is determined by conditions in the very early stages. As early as 1914 Hjort (1914, p. 204) stated: "The rich year classes thus appear to make their presence felt when still quite young; in other words, the numerical value of a year class is apparently determined at a very early stage and continues in approximately the same relation to that of other year classes throughout the lifetime of the individual." Again, in discussing which stage of development forms the most critical period, he added: "Such data as are available, however, appear to indicate the very earliest larval and young-fry stages as most important."

In studying the distribution of fish eggs and larvæ it is necessary to distinguish between those species that collect on definite grounds to spawn and such pelagic forms as the mackerel, which appear to spawn over extended areas, irrespective of depth or bottom. The different starting points of the eggs must be taken into consideration in interpreting movements in the latter species. The gadoids (cod, haddock, and pollock), which have limited spawning areas, may be included as one group, although they are not particularly favorable for a group study, having different spawning areas as well as somewhat different breeding seasons. For that reason only the cod (*Gadus callarias*) will be considered in the present paper.

The breeding areas of the cod may be divided into two groups—the inshore grounds and the offshore grounds. Among the latter may be mentioned Nantucket Shoals, Georges Bank, Western Bank, and the Grand Bank. Ipswich Bay and the spawning area off Plymouth are perhaps the most important of the inshore grounds on the New England coast.

The present paper is concerned with the results of an investigation to determine the importance of Massachusetts Bay as a production center for cod and also its part

in the natural economy of the region. It had been suggested that the southwest current or drift along the Maine coast carries eggs and early fry into Massachusetts Bay, which, protected by the arm of Cape Cod, serves as a nursery not only for those entering from the east but also for large numbers spawned in the bay itself, where the young cod find ample food and are protected from storms and winds until large enough to take care of themselves. It had even been suggested that this area might form an important source of supply for the codfish of the whole coast of New England.

PREVIOUS EVIDENCE OF COASTAL DRIFT IN THE GULF OF MAINE

That a definite southerly drift or set exists along the whole western margin of the Gulf of Maine is indisputable. Since earliest times fishermen have known of the "so'west current" and utilized it in navigation. At times its inner margin is defined clearly by slicks or, on calm days, by a line of seaweed and other floating débris.

Drift-bottle and current experiments by Mavor (1920 and 1922), Bigelow (1927), and Dawson (1905) have shown not only the direction of the drift but also have contributed considerable information on its rate of movement. (See fig. 1.) Mavor found that the set in summer and autumn averaged about 4 miles per day, and Bigelow (1926) suggests that in spring it is probably higher than that. To the drift-bottle evidence may be added the very extensive data on the general circulation obtained by the latter author from current measurements, temperature and salinity distribution, and dynamics, all of which substantiate the existence of a definite counterclockwise set around the gulf.

Earlier observations on egg and larval-fish distribution also indicate a movement from the northeast to the southwest. Based on evidence accumulated in the Gulf of Maine since 1912, Bigelow (1926, p. 75) concluded: "Thus fish eggs and larvæ, and for that matter every member of the plankton, animal or vegetable, tend to follow the same peripheral migration zone as do the immigrants that enter the eastern side of the gulf in the upper 50 meters." Also, "At the times when the dominant drift of the surface water follows the coast line closest, south toward Cape Ann, Massachusetts Bay probably acts to some extent as a catch basin for all sorts of flotsam from the north, living, of course, as well as dead, as it did for certain of Mavor's drift bottles. The chart (fig. 2) suggests that larvæ that pass Cape Ann tend to be caught up in the backwater of the bay, to remain there until they abandon the pelagic life for the bottom. Thus it is probable that the rich fish fauna of the bay and its adjacent waters is regularly recruited from the north and east."

The scarcity of eggs reported by Bigelow in the Gulf of Maine east of Mount Desert and the increasing numbers toward the west, combined with the fact that one of the most important of the inshore spawning grounds (Ipswich Bay) is situated just north of Cape Ann, seemed to be assurance in itself of an ample supply of developing eggs and pelagic fry, even if no breeding grounds had existed within the confines of Massachusetts Bay itself; but catches extending over a long period of years from the grounds off Plymouth have shown that this bay harbors one of the largest of the inshore breeding centers and one that supplies a large percentage of the eggs hatched each year at Gloucester. Between November 24, 1911, and January 3, 1912, 67,032,000 cod eggs were collected from Plymouth by the Gloucester hatchery; and in 1925–26 these same grounds were one of the principal contributors to the 1,219,468,000 cod

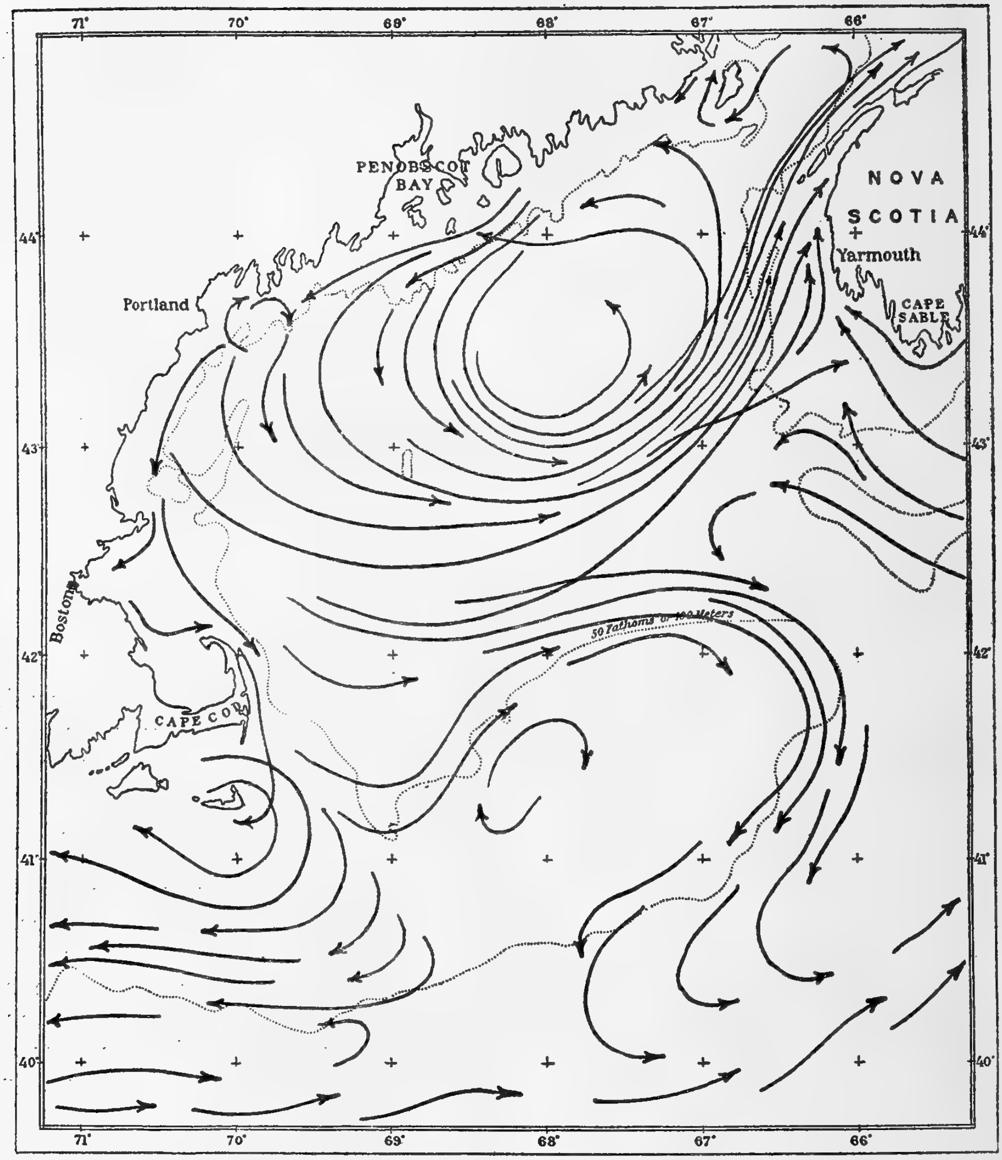

FIG. 1.—Dominant circulation of water in the Gulf of Maine. (After Bigelow.)

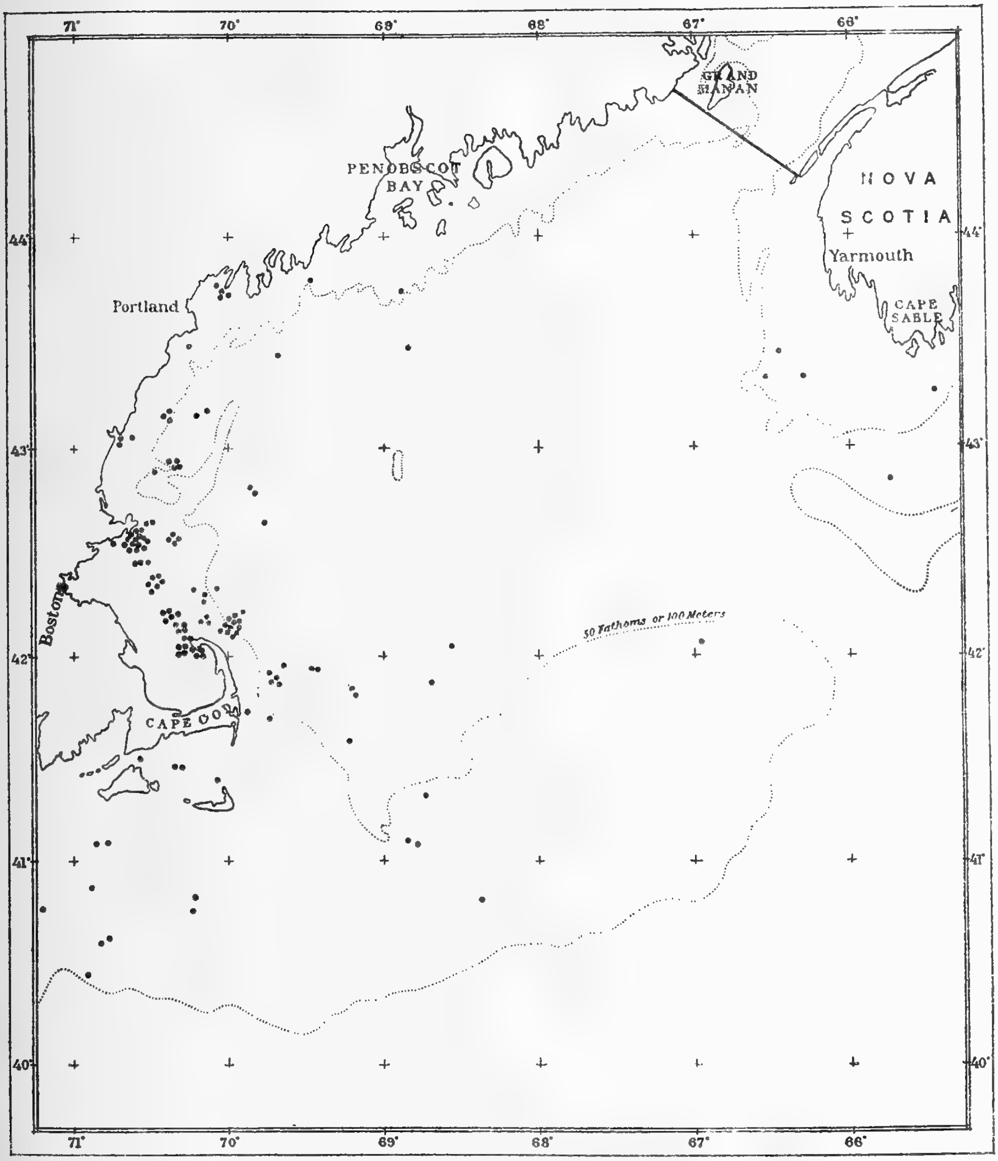

FIG. 2.—Locality records for flounder (pleuronectid) and gadoid larvæ (a dot for each record of each species), to illustrate the probable drift of buoyant fish eggs and larval fishes. (After Bigelow.)

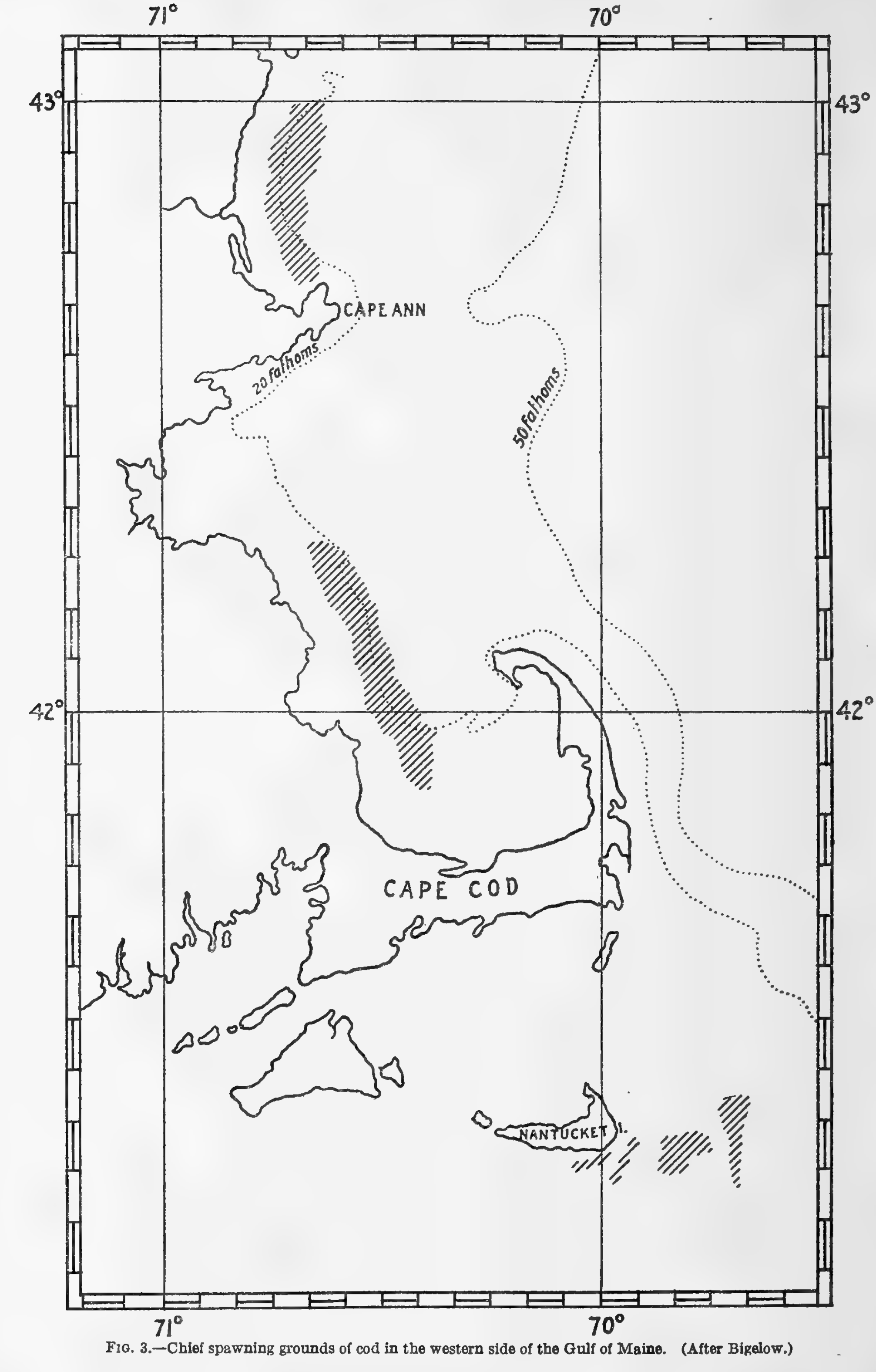

FIG. 3.—Chief spawning grounds of cod in the western side of the Gulf of Maine. (After Bigelow.)

eggs obtained by the same hatchery. In addition to this, 430,648,000 pollock eggs also were obtained, 90 per cent of which were derived from gill nets operating around Plymouth and Duxbury. Therefore there was every reason to believe that we would find Massachusetts Bay a haven for an immense number of eggs and fry and a nursery containing young cod in all stages of development. It was expected, too, that this locality would prove favorable for a study of the early life history of this species, its rate of larval development, vertical movements, food during this period, enemies, and the gradual changes in the feeding habits and migrations during the first year of its existence. This investigation was also to form the first of a series of investigations to determine the relative importance of the various fishing banks as production centers.

PROGRAM AND METHODS

SPAWNING AREAS EXAMINED

The area selected for study (fig. 3) comprises the two most important inshore spawning grounds on the New England Coast—Massachusetts Bay and the adjacent grounds to the north (Ipswich Bay). In many respects the conditions are very much alike in the two localities, both being in very shoal water and limited to small and very well defined areas. Off Plymouth the grounds run parallel with the coast, 3 to 10 miles from shore, and reach from abreast of Sandwich to Minot's Light. Roughly, the Ipswich grounds extend from the Isle of Shoals to Cape Ann, chiefly within 4 to 6 miles of land. (Bigelow and Welsh, 1925.) The Massachusetts Bay grounds range from 22 to 46 meters in depth and the Ipswich grounds 9 to 46 meters. Although ripe cod may be found in either of these localities from September to May, the height of the spawning season is reached at different times.

SPAWNING SEASON

The local fishermen say that the cod strike in the shallow water off Plymouth about November 1 and, according to Bigelow and Welsh (1925), reach the height of their spawning season from December through January, when the water ranges from 2.2 to 5.5° C. Hatching records and the abundance of eggs in collections from these grounds in 1925 indicate that spawning fish were plentiful throughout the winter and spring. Until March 20, the Gloucester station received 25,000,000 to 30,000,000 cod eggs daily from the Plymouth grounds.

In Ipswich Bay the height of the cod-spawning season is reached in March, much later than south of Cape Ann, although a few small breeding areas of lesser importance along the north side of Massachusetts Bay, particularly in the vicinity of Pig Rock, off Gloucester, form a haven for spring breeders. Here the season is said to coincide with that at Ipswich, spawning taking place throughout the coldest part of the year, when the temperature ranges from 0.56 to 3.05° C.

COD AND HADDOCK EGGS

As haddock eggs in their early stages are indistinguishable from cod eggs, distribution charts must be interpreted in the light of our knowledge of the probable points of origin and the direction of the drift. Were there no drift, it would be possible to determine the relative percentage of cod and haddock eggs containing late embryos and then assume that the earlier stages were present in the same propor-

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tions. The difference in the location of the breeding centers of the two species, however, makes this impossible, for, as will be shown, the drift that carries cod eggs out along the south side of Massachusetts Bay brings haddock eggs in from the north and east. As the spawning center of the haddock is in the outer part of the bay, the percentage of cod eggs in early cleavage about Plymouth would be expected to far exceed the haddock, which probably would be in later stages when they reached that point. Similarly, the percentage of haddock eggs containing early embryos should outnumber the cod. Table 5 shows the abundance of eggs in the bay on April 21, at the height of the haddock season. A single surface haul with a foot net at station 18A yielded 8,148 eggs. No such quantities of cod eggs ever were found either at Plymouth or Ipswich.

ITINERARY

Fourteen cruises in all were made and 38 stations visited from December 3, 1924, to June 17, 1925. (See Table 1.)

Starting from Minot's Light, off Boston Harbor (station 17), the stations extended completely around the arm of Cape Cod as far as Provincetown, and from there across the bay to Boston, with three stations on Stellwagen Bank. (Fig. 4.) Later stations were added over the deeper parts in the center of Massachusetts Bay (stations 18, 18A, and 19), a line run along the north shore (stations 29 to 38), and a line across the entrance from Cape Ann to a point off Highland Light (stations 30 to 34).

TABLE 1.—"*Fish Hawk*" *stations, November 12, 1924, to June 17, 1925, Massachusetts Bay*

Station	Latitude (north)			Longitude (west)			Station	Latitude (north)			Longitude (west)		
	°	′	″	°	′	″		°	′	″	°	′	″
1	42	01		70	34		15	42	09	30	70	38	15
2	42	12		70	23	30	16	42	14		70	41	
3	42	09	30	70	19	30	17	42	18	15	70	44	
4	42	06		70	17		18	42	18	30	70	32	30
5	42	01		70	12		18A	42	16	54	70	30	30
6	41	55	30	70	9	30	19	42	22		70	38	
6A	41	56	00	70	18	30	29	42	38	00	70	33	30
7	41	49	15	70	11	30	30	42	38	00	70	25	15
8	41	49		70	24	30	31	42	30	30	70	20	30
9	41	53	15	70	27		32	42	23	30	70	15	30
10	41	58		70	30	15	33	42	15	30	70	10	30
11	41	59	30	70	31	30	34	42	07	45	70	06	30
11A	42	00	00	70	32	15	35	42	34	30	70	38	00
12	42	01	15	70	33		36	42	30	15	70	43	15
13	42	03		70	34	30	37	42	28	00	70	48	00
13A	42	02	30	70	34	00	38	42	24	15	70	52	15
14	42	05		70	35								

TABLE 2.—"*Fish Hawk*" *stations, November 12, 1924, to June 17, 1925, Ipswich Bay*

Station	Latitude (north)			Longitude (west)			Station	Latitude (north)			Longitude (west)		
	°	′	″	°	′	″		°	′	″	°	′	″
20	42	44	00	70	36	45	25	42	52	00	70	40	00
21	42	46	00	70	40		26	42	53	30	70	43	00
22	42	47	45	70	43	30	27	42	54	30	70	40	00
23	42	49	30	70	40	00	28	42	56	00	70	41	45
24	42	50	30	70	43	30							

It was originally planned to cover the area every week during the spawning season, and between December 3 and December 23, 1924, four trips were made. How-

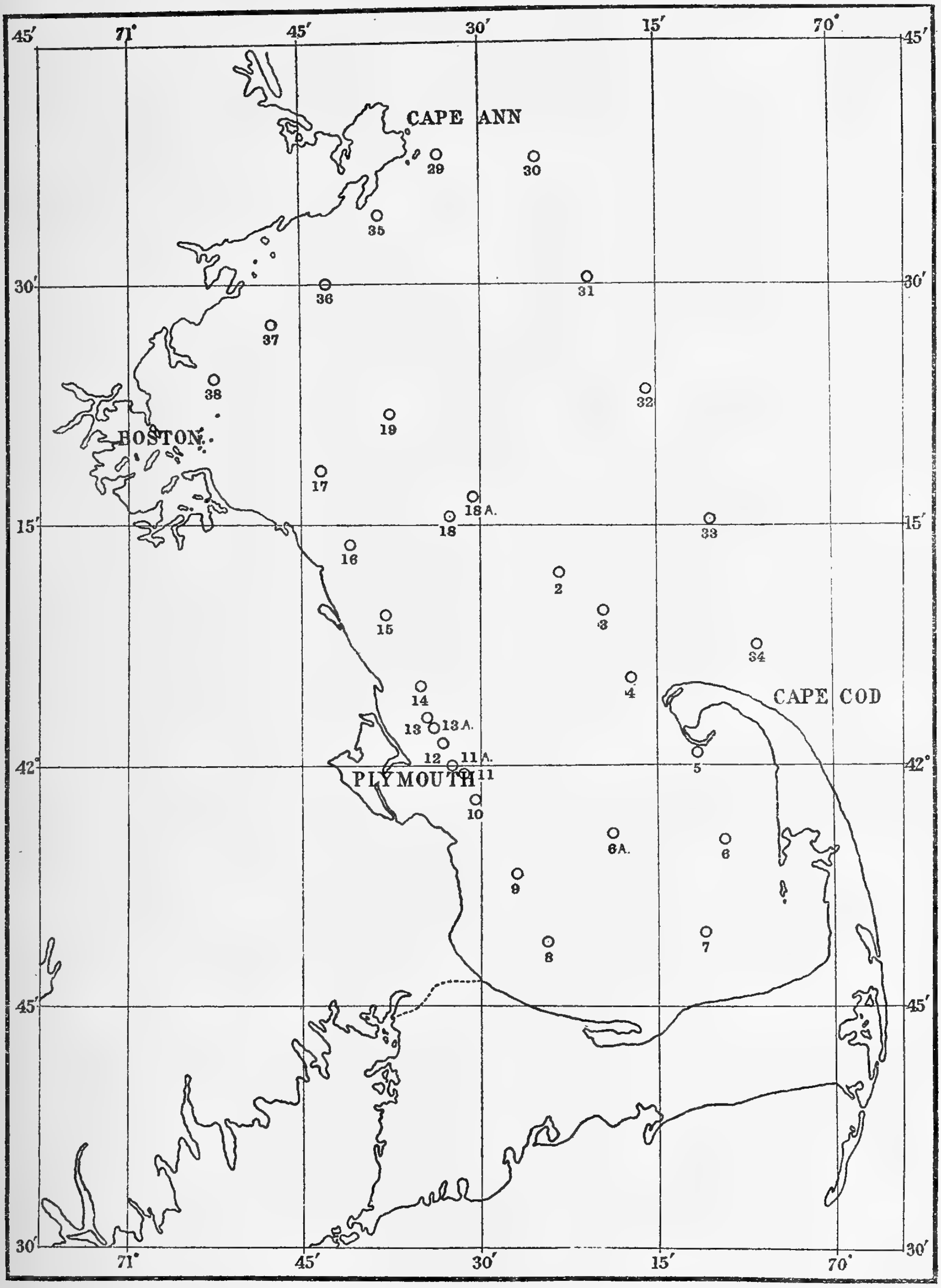

Fig. 4.—*Fish Hawk* stations in Massachusetts Bay, 1924-25

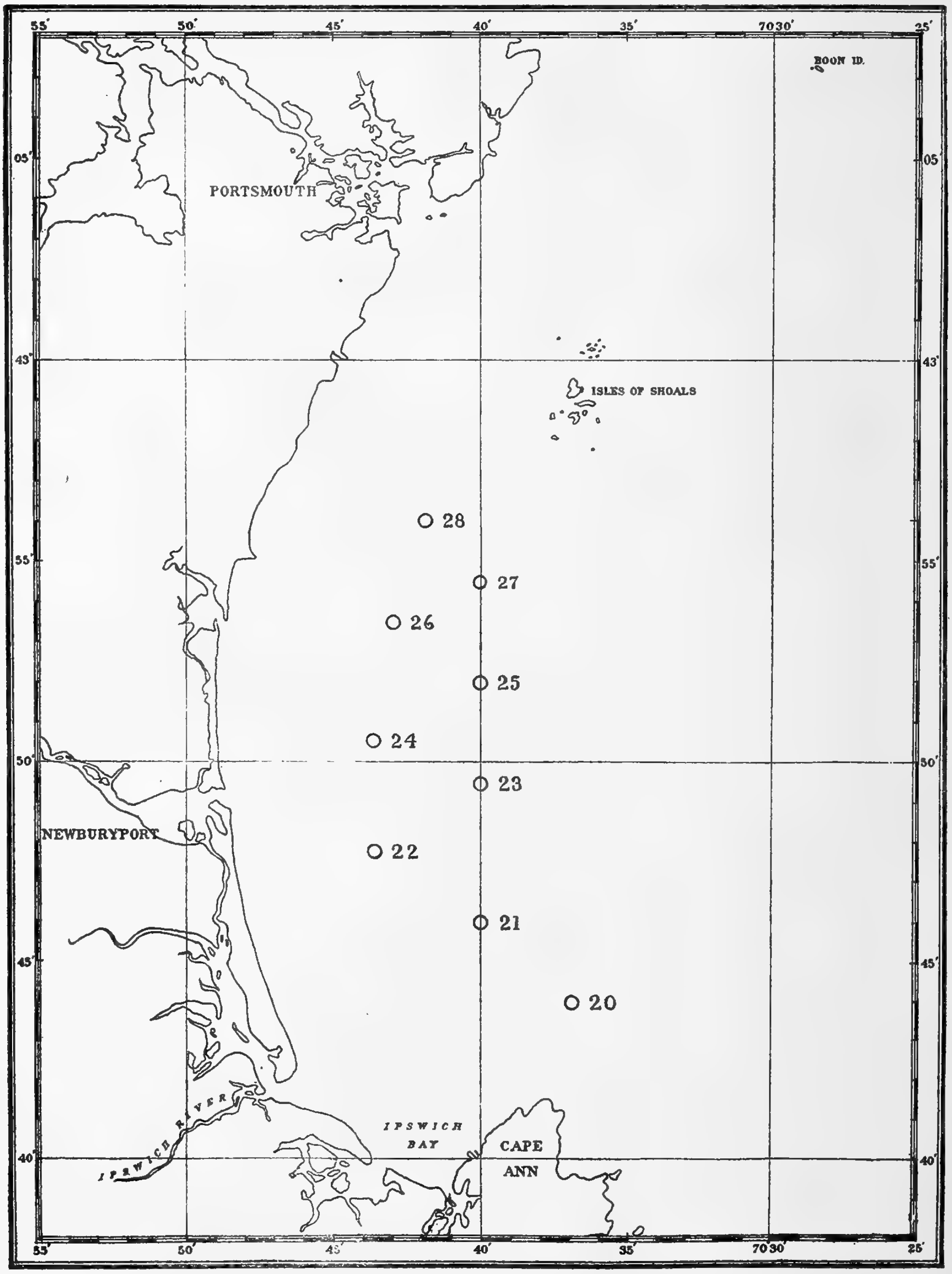

FIG. 5.—*Fish Hawk* stations in Ipswich Bay, 1924–25

ever, due to the need of increasing the number of stations (thus prolonging the cruises), and to the frequent delays that were inevitable during the severe winter season, the interval between trips was increased later to two weeks.

Cruise	Date	Cruise	Date
1	Dec. 3, 1924.	8	Mar. 10, 1925.
2	Dec. 9–11, 1924.	9	Mar. 12, 1925.
3	Dec. 16–17, 1924.	10	Mar. 25, 1925.
4	Dec. 22–23, 1924.	11	Apr. 7–8, 1925.
5	Jan. 6–7, 1925.	12	Apr. 21–23, 1925.
6	Feb. 6–7, 1925.	13	May 20–22, 1925.
7	Feb. 24–28, 1925.	14	June 16–17, 1925.

EQUIPMENT AND METHODS

The collections made at each station consisted of a vertical haul, two 20-minute surface hauls (one coarse and one fine net), and a 20-minute haul near the bottom with a coarse net. In order to facilitate the work, advantage was taken of the very extensive data on temperature and salinity variations in the Gulf of Maine previously obtained by Doctor Bigelow, and only such physical observations were made as were necessary to interpret the existing conditions and to serve as a basis for comparison with previous years (see Table 15). These consisted of temperature readings from various levels and, at times, salinity determinations. Most of the latter were computed by Richard Parmenter from hydrometer readings. Greene-Bigelow water bottles, with reversing deep-sea thermometers (Richter and Schmidt-Vossberg), were used.

Vertical hauls were made with a Michael Sars meter net, the upper 1½ meters (nearest the large opening) being of No. 00 silk bolting cloth and the lower three meters of No. 2 silk. The fine surface net of No. 20 silk was 1 foot in diameter at the opening and 3 feet long. Michael Sars meter nets of the same type as the vertical nets were used for surface and bottom towing.

Drift bottles were set out at various places in order to supplement the evidence of water movement indicated by the cod eggs. (Figs. 14 and 15.)

Between November 12, 1924, and June 17, 1925, more than 650 net collections were made and the distribution of the eggs was plotted by trips. Considerable error, no doubt, has entered into the results, but this is unavoidable in work of this type, where so many hauls and such large quantities of eggs are involved. The use of horizontal nets for quantitative work may be criticized, but, as has been pointed out often (Bigelow, 1917; Fish, 1925, etc.), unless the desired species are present in extremely large numbers, the catches with a vertical haul are too small to be of any value; and even when abundant, they are so unequally distributed usually that the results are more likely to be misleading than helpful. Again, conclusions based entirely on surface hauls might prove equally erroneous if the eggs were concentrated at the lower levels. Had there been ample time and funds, more accurate figures might have been obtained, and the difficulties arising from "streaky distribution" overcome to some extent by greatly increasing the number of stations and plotting results based on vertical hauls alone. This was not possible at the time, however; therefore the sum of the yields of one vertical haul and one 20-minute surface haul from each station has been used in preparing charts on the

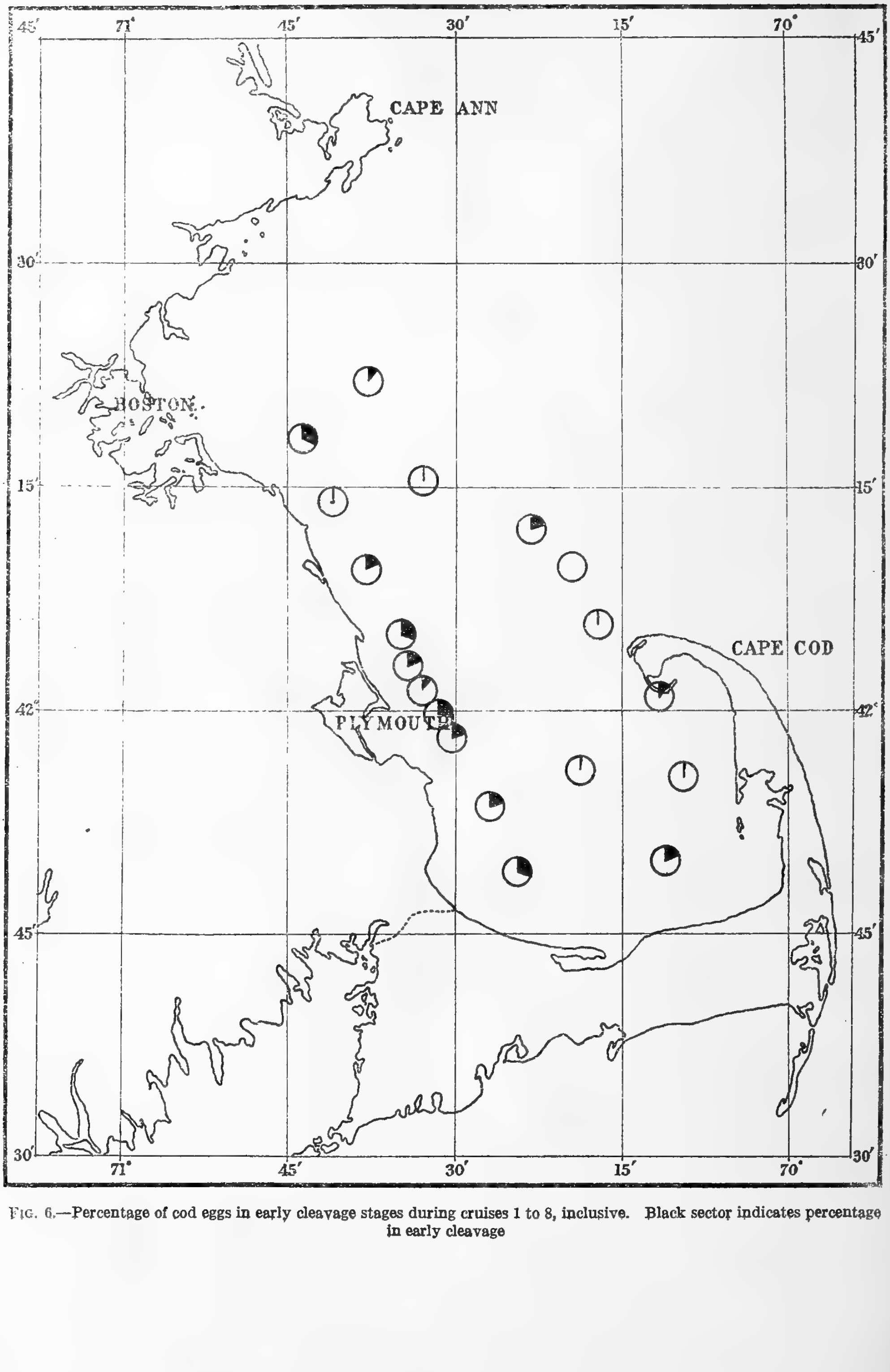

FIG. 6.—Percentage of cod eggs in early cleavage stages during cruises 1 to 8, inclusive. Black sector indicates percentage in early cleavage

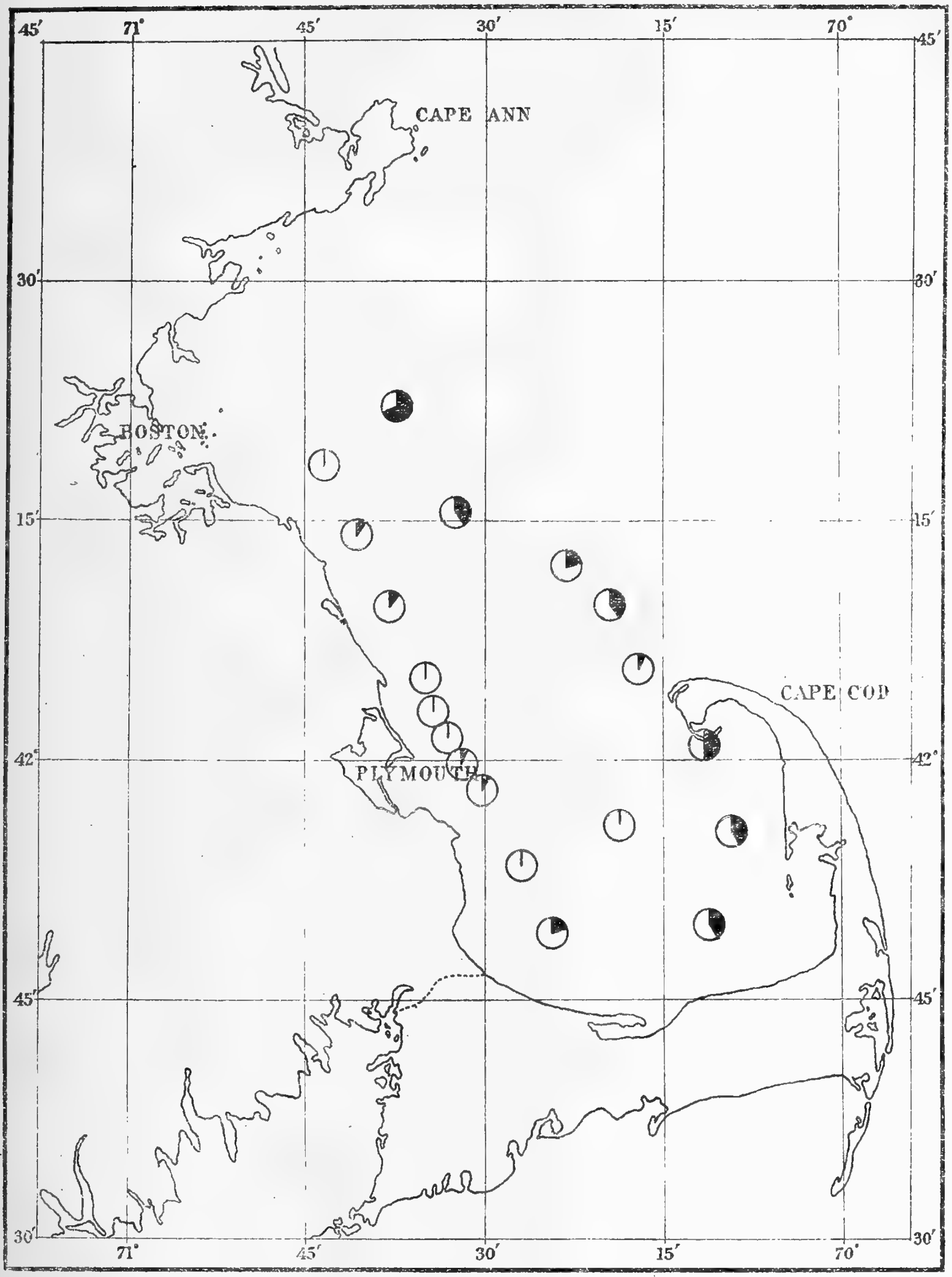

FIG. 7.—Percentage of cod eggs containing late embryos during cruises 1 to 8, inclusive. Black sector indicates percentage of late embryos

distribution of the pelagic eggs. The slight variation in the depth of the vertical hauls (a matter of a few meters at most) becomes insignificant when included with a 20-minute horizontal haul.

In examining the eggs the following stages were distinguished and recorded: Early cleavage, late cleavage, early embryo, and late embryo. Later, in preparing the charts, only the early-cleavage and the late-embryo records were used.[1] This extreme contrast facilitated the plotting and also simplified the results.

In making composite charts to show the general movements of the eggs the first eight cruises and the last four have been combined in two groups. This was done in order that the first group would not be complicated by the great influx of haddock eggs from the northeast in the late spring.

SUMMARY OF OBSERVATIONS

GENERAL CONDITIONS

The problem, as already stated, involved a determination of the value of Massachusetts Bay as a production center for cod and also as a nursery for the large number of eggs and larvæ that we had reason to believe were being transported in continually as contributions from the spawning grounds to the north and east. It is known that of the millions of eggs liberated on cod banks, probably few escape fertilization, and also that under normal conditions these eggs tend to float near the surface. (Prince, 1909.) Ample stations were selected to allow for a determination of the distribution of eggs and larvæ within the bay at any one time. By preparing charts on the distribution of eggs in various stages of development it was hoped that the directions and rate of dispersal would be shown.

THE ABSENCE OF FRY

On the 14 trips hundreds of hauls were made and thousands of eggs were obtained, but not one larval cod appeared. It was evident that the eggs were disappearing before they hatched. To ascertain whether they were concentrated at some particular depth, hauls were made at all levels but without success. No cod fry appeared although larval pollock and later larval haddock were fairly numerous sometimes.

DEFINITE DRIFT OF EGGS

Charts based on the distribution of eggs almost without exception indicated a concentration of early stages over the spawning grounds and of later stages along the lower arm of Massachusetts Bay, and particularly in the outer parts. (See figs. 6 and 7.) Thus, on the first 8 cruises, 88.7 per cent of the eggs taken at station 11 (in the heart of the Plymouth grounds) were in early-cleavage stages and only 11.3 per cent contained embryos. These figures become even more significant when divided into four groups, 30.8 per cent of the eggs being in early cleavage, 57.9 per cent in late cleavage, 7.9 per cent containing early embryos, and 3.4 per cent late embryos. Contrasted with this, station 3 (at the outer entrance to the bay) yielded not one egg in early cleavage, but 40 per cent were late embryos.

[1] These two stages in the present paper are distinguished as follows: Early cleavage extends from fertilization to a point where the exact cleavage stage can not be distinguished easily (32 to 64 cell stage). In late embryos the chromatophores are arranged in groups and give the characteristic banded appearance.

LOCAL PRODUCTION IN MASSACHUSETTS BAY

The Plymouth grounds could easily be established as the production center for locally spawned eggs throughout the season of 1924–25; and even during the great influx of haddock and cod eggs from the east in the late spring (fig. 8), as will be described later, the charts show unmistakable evidence of local production.

Figures 6 and 7 indicate the distribution of eggs in early-cleavage and late-embryo stages, based on the results of the first eight cruises. In Figure 6, extending all along the western shore from station 17 to station 8, the large percentages of eggs in early cleavage indicate the production area. By comparing this figure with Figure 7, it will be seen that elsewhere in Massachusetts Bay later stages dominate.

Production on the Plymouth grounds is illustrated further by the following table, showing the number of eggs taken on each cruise at station 15, on the northern part of the grounds, and the increased numbers that had accumulated by the time the drift reached station 10, on the southern part. The percentage of eggs in cleavage stages is included to show that locally spawned eggs were being dealt with and not immigrants from some distant source.

TABLE 3

Cruise	Station 15		Station 10	
	Total number of eggs taken	Percentage in early cleavage	Total number of eggs taken	Percentage in early cleavage
1	9	77.8	28	49.9
2	2	100.0	14	56.0
3	17	58.8	519	53.2
4	30	100.0	26	92.4
5	24	75.0	298	93.0
6	0	0.0	17	11.7
7	15	53.3	265	63.5
8	9	100.0	243	80.3

EXTENT OF THE SPAWNING SEASON ON THE PLYMOUTH GROUNDS

The collections also afford considerable information on the duration of the spawning season on the Plymouth grounds in 1924–25. Before starting the regular cruises with the *Fish Hawk*, two visits were made to these grounds, the first on November 12. Spawning had already begun at that time, although the temperature of the water had dropped to only 10.1° C. A 20-minute haul with a foot net (No. 0 silk) yielded 53 eggs, all in early-cleavage stages. These can safely be called cod, both because of the abundance of ripe cod present and also because haddock spawning had not begun. Of 11 adult cod, ranging from 5 to 50 pounds, taken at random from a trawl at this time, 6 were females and 5 were males. One female was still green, one nearly ripe, two ripe, and two nearly spent. Of the males, one was green and four were ripe. On November 20 a second haul on the same grounds yielded 65 cod eggs, all, with the exception of one (an early embryo), in cleavage stages. Some

idea of the length of the season may be obtained from the following table, giving the average number of eggs in cleavage stages per station on the Plymouth grounds:

TABLE 4

Trip	Date, 1924-25	Average number of eggs	Trip	Date, 1924-25	Average number of eggs
1	Dec. 3	26	7	Feb. 24-25	71
2	Dec. 9-11	46	8	Mar. 10	70
3	Dec. 16-17	57	11	Apr. 7-8	304
4	Dec. 22-23	24	12	Apr. 21	167
5	Jan. 6-8	72	13	May 20-22	10
6	Feb. 6-7	8			

This table shows clearly the increase in production as the spawning season progressed and also the destruction of eggs by the storms that occurred at the time of the fourth and sixth cruises. (See p. 286.) Up to the time of cruise 8, for reasons given on page 274, it is safe to assume that most of these were cod.

Omitting for the moment the small returns on December 22 and February 6, which obviously represent artificial results (p. 286) and give no indication of the true production that took place at the time, the figures on the Plymouth grounds show that spawning had already begun on November 12, increased through December, and reached its height in January, February, and early March, although, as will be shown later, considerable spawning, no doubt, took place throughout April. Taken alone, this table gives no indication of the end of the breeding season at Plymouth, for in late March and early April the great influx of haddock and cod eggs from the east (fig. 8) complicated the results and made it impossible to distinguish locally spawned eggs from the immigrants.

Extending the area to cover all of Massachusetts Bay and computing the average number of eggs per station, it is seen that the conditions at Plymouth reflect very well the general conditions for the whole bay, as would be expected if that locality forms the source of supply.

TABLE 5

MASSACHUSETTS BAY

Trip	Number of stations	Total number of eggs	Average number of eggs per station	Mean surface temperature (° C.)	Mean bottom temperature (° C.)	Date
1	9	222	25	6.14	6.13	Dec. 3.
2	15	445	30	6.20	6.25	Dec. 9-11.
3	14	797	57	5.02	5.46	Dec. 16-17.
4	13	250	19	4.30	4.75	Dec. 22-23.
5	14	699	50	2.54	2.60	Jan. 6-8.
6	15	236	16	.75	.95	Feb. 6-7.
7	7	1,083	155	1.65	1.68	Feb. 24-25.
8	6	305	51	2.00	1.89	Mar. 10.
11	14	1,962	140	4.59	3.40	Apr. 7-8.
12	20	20,761	1,038	5.27	4.02	Apr. 21.
13	20	4,542	239	8.89	4.57	May 20-22.
IPSWICH BAY						
9	5	319	64	3.54	2.50	Mar. 12
10	8	940	117	3.54	2.72	Mar. 25.
11	4	508	127	4.61	2.64	Apr. 7.

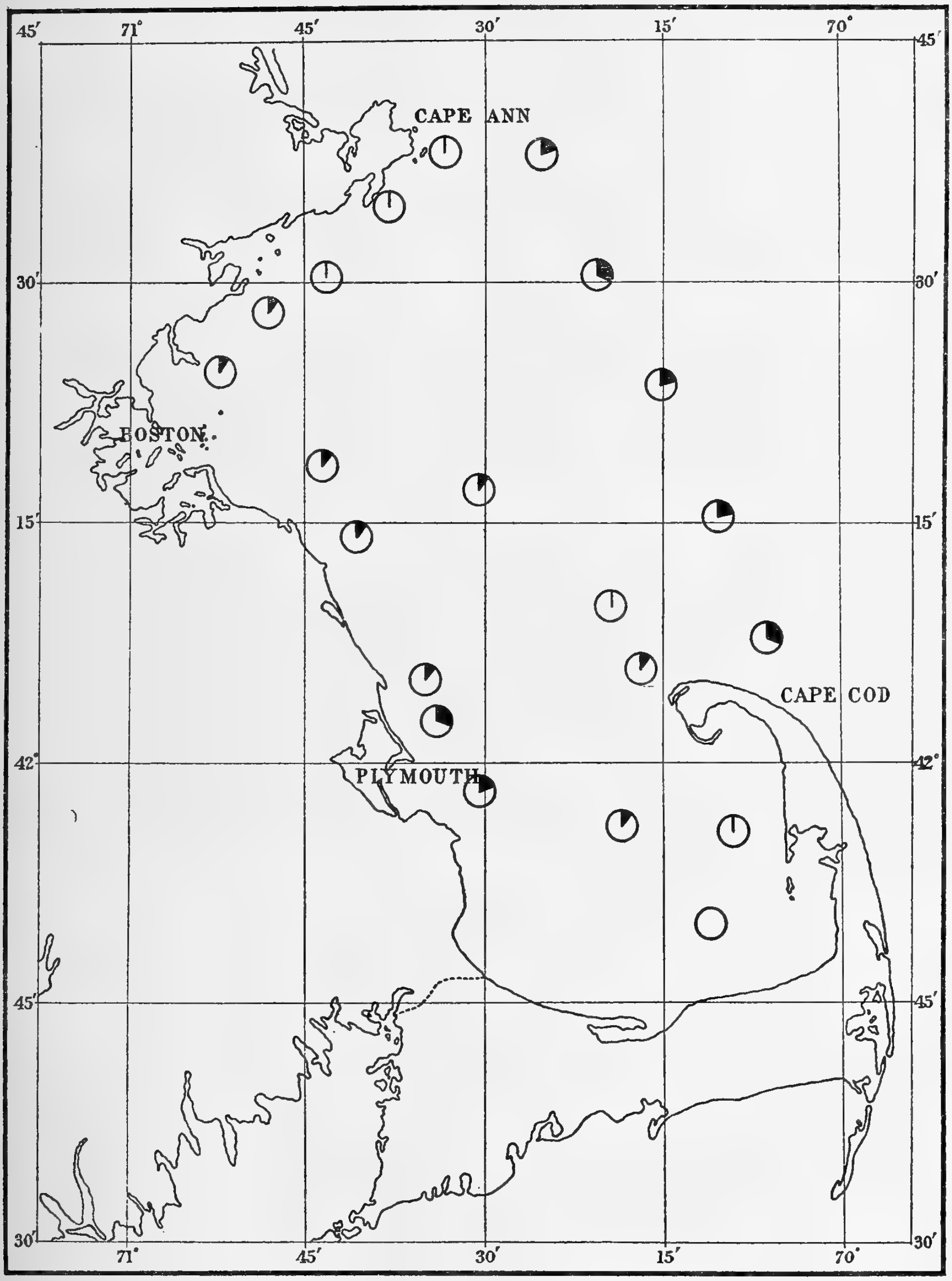

FIG. 8.—Percentage of eggs in early cleavage stages during cruises 9 to 12, inclusive. Black sector indicates percentage in early cleavage

Here, again, the destructive effects of storms (p. 268) are evidenced by the small returns from trips 4 and 6. The increase through December and January, reaching its peak in late February about the time of the seventh cruise (February 24–25), and then the decline until overcome by the invasion from the east, corresponds very well in the two tables. In each the influx became evident on cruise 11.

In comparing these two tables it will be noticed that, although the number of eggs taken in Massachusetts Bay on the twelfth cruise (April 21) was more than four times that taken on any of the other cruises, the actual number of eggs in cleavage stages on the Plymouth grounds had declined to approximately one-half that of the trip in the previous month. The influx of eggs from the outer waters was supplemented to some extent, no doubt, by locally spawned eggs even on April 21, but by May 20–22 local spawning had virtually ceased. This point is very well brought out also by a comparison of Figures 8 and 11. The former, based on the results of trips 9 to 12, shows the quantities of newly spawned eggs in the outer waters but at the same time indicates clearly that considerable production was still taking place on the Plymouth grounds. Figure 11, giving the quantitative distribution of eggs a month later, shows that by May 20, 1925, production on these grounds had virtually ceased, and the large numbers recorded for this cruise (Table 5) are seen to be concentrated in the outer parts of the bay and along the northern side.

The large number of eggs entering from the east was probably the result partly of contributions from the Ipswich grounds and partly of haddock eggs drifting in from the northern part of Stellwagen Banks (favorite spawning grounds for that species) or from the waters east of Cape Ann; for, as already stated, haddock do not spawn in abundance in the inner parts of the bay and few, if any, on the grounds off Plymouth. (Bigelow and Welsh, 1925.)

According to Bigelow and Welsh (1925), the height of the cod spawning season at Plymouth is reached during the period of falling temperature, the bulk of the eggs being liberated before the winter minimum is reached. In 1924–25 the height of the season apparently was reached in February and extended through the coldest part of the year, when the mean surface temperature ranged from 2.54° to 0.75° C. In this it agreed with previous observations at Ipswich, where the greatest production is known to take place during the period of minimum temperatures.

DRIFT AS INDICATED BY THE EGGS

The determination of spawning areas by locating the centers of distribution of eggs in early cleavage and then following the general movement from these centers by charting the distribution of eggs in progressively advanced stages of development is not new. In 1914 Hjort reported that cod eggs in early development had been found to be restricted to very limited areas and suggested the possibility that these eggs might serve as a basis for determining the position of the spawning shoals. As early as 1900, however, this same author stated that in European waters cod fry often are carried for hundreds of miles, being distributed over the banks off the northern coast of Norway and especially in the Barents Sea, where they may be taken the following year in fine-meshed nets on the bottom.

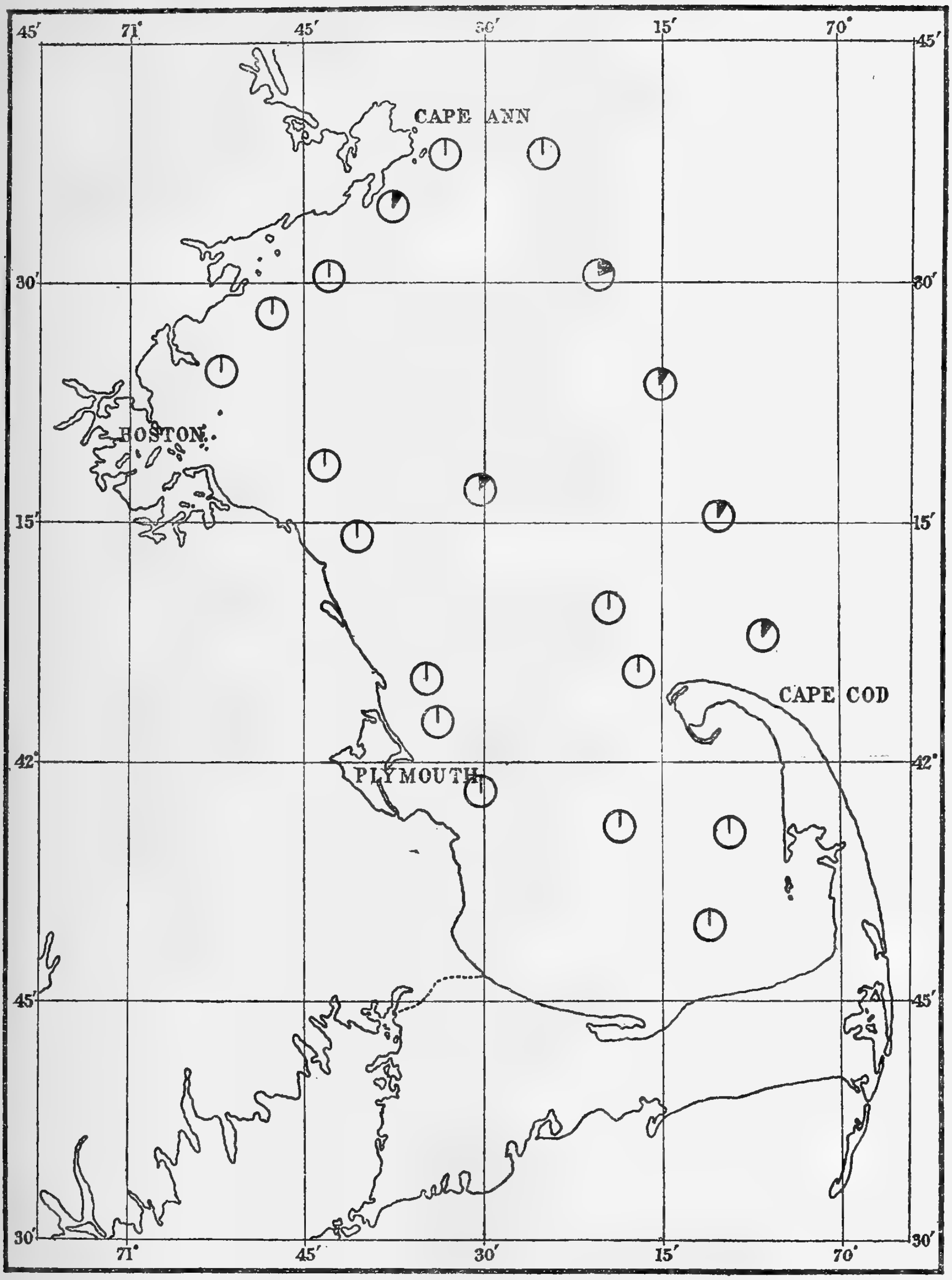

FIG. 9.—Percentage of eggs containing late embryos during cruises 9 to 13

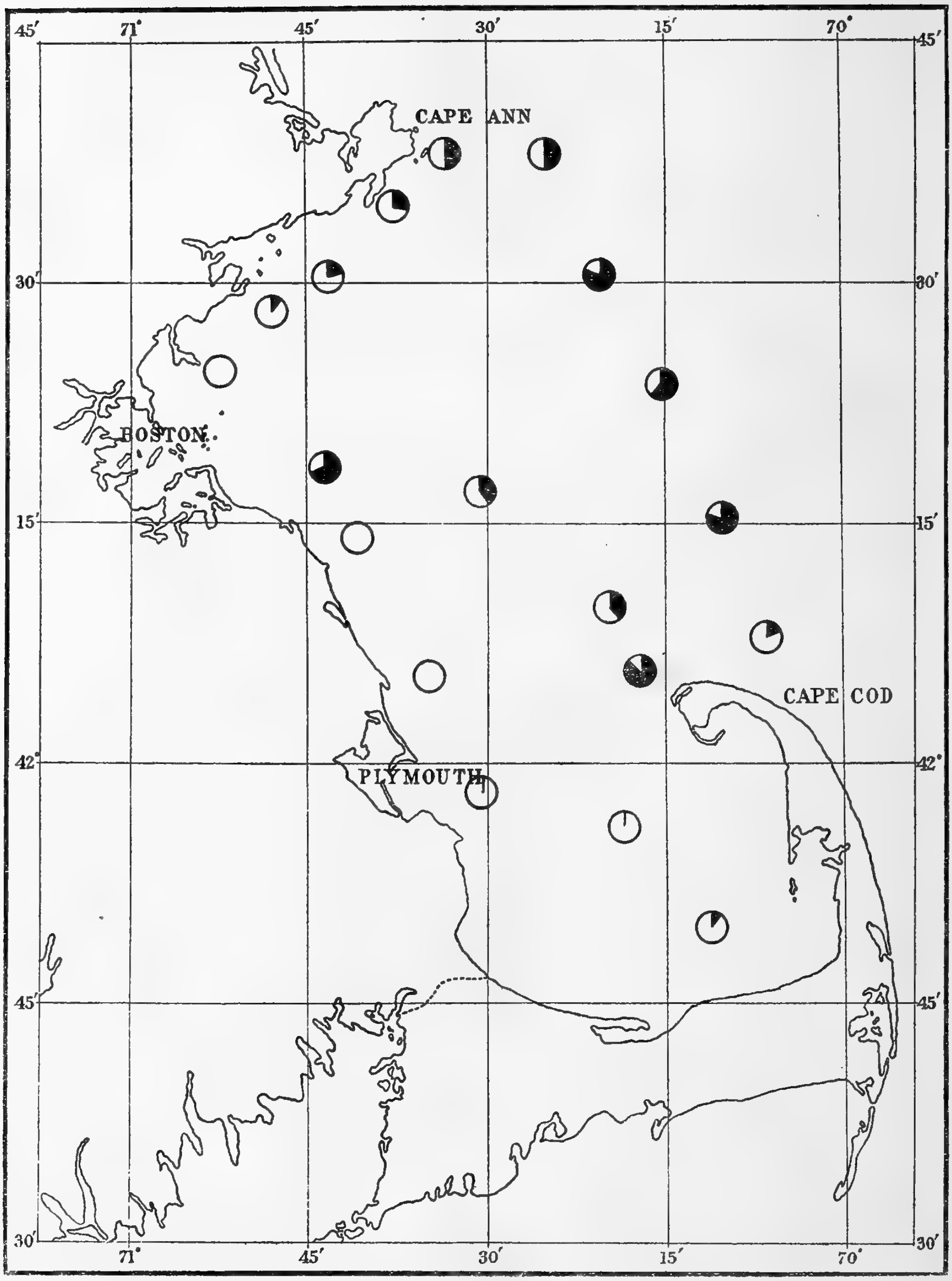

FIG. 10.—Percentage of eggs containing embryos during cruise 13 (May 20–22, 1925). Black sector indicates embryos

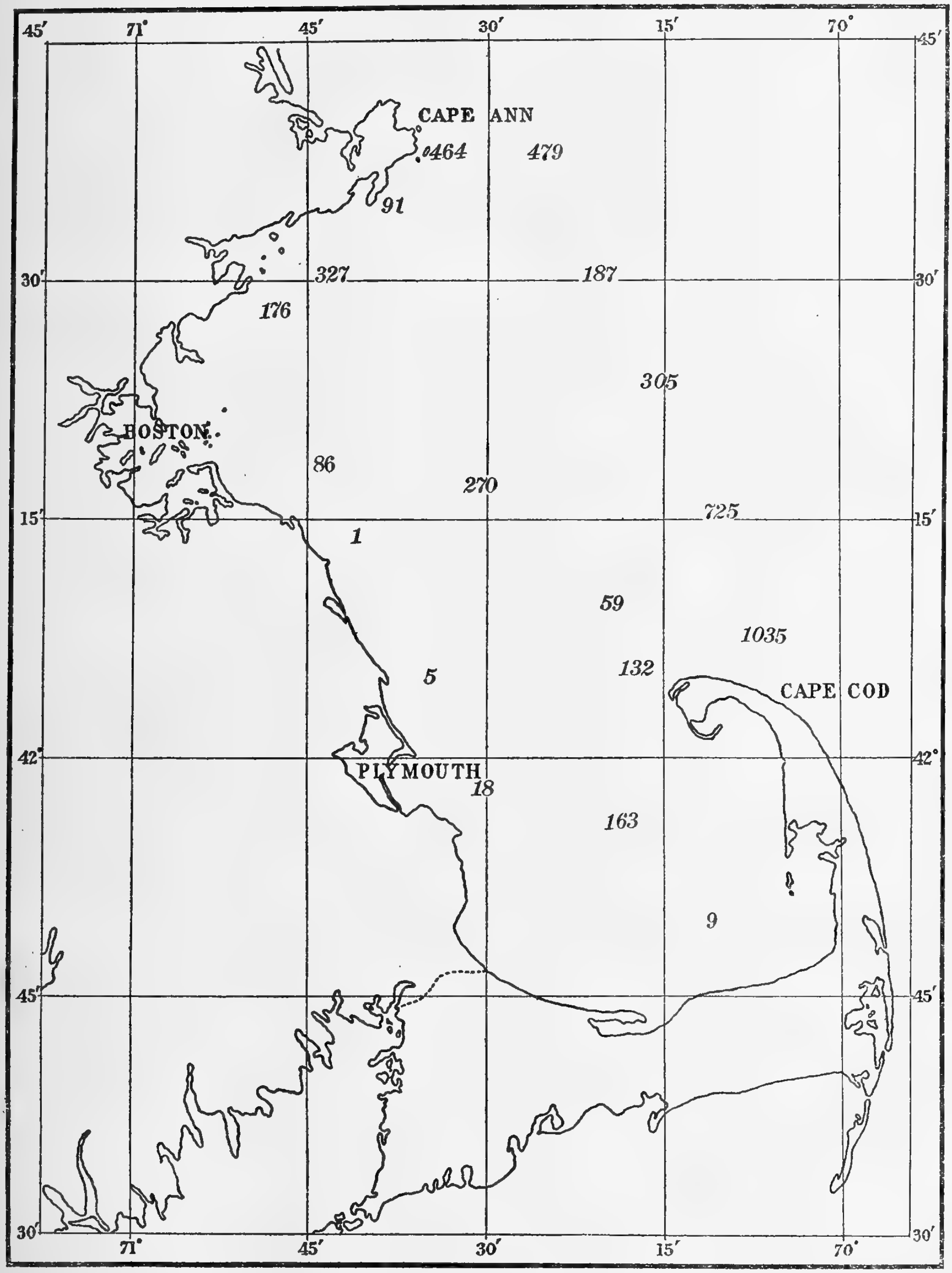

FIG. 11.—Quantitative distribution of eggs in Massachusetts Bay during cruise 13 (May 20–22, 1925), showing influx of cod-haddock eggs from the east

Were there no dominant drift, but only tides and winds, to scatter the eggs, one would find newly spawned eggs and those in early cleavage stages over the spawning grounds and over a large area a mixture of eggs and larvæ in various stages of development. Contrasted with a condition of this sort, in regions subjected to a definite drift flowing in one direction, we should expect to find over the spawning grounds only eggs in the earliest stages of development, provided there were no other complicating influences, such as storms, tidal actions, or neighboring spawning areas nearer the source of the drift. Following the course of the current from the grounds, eggs should be found in progressively later stages of incubation, the distances traveled before hatching depending on two factors—temperature (as this increases or retards the rate of development) and the rate of the drift. In localities where a very rapid drift passes over the grounds the eggs might be carried great distances before hatching, provided the temperature were low enough. For example, eggs incubating in a temperature of 1° C. (February temperature in Massachusetts Bay) and subjected to a drift of 4 miles a day might travel more than 120 miles before hatching, and the fry then might drift for two to two and a half months. Those fry might then seek the bottom 420 miles from the spawning grounds. This, of course, is merely a hypothetical case, but it illustrates a possible occurrence. Consequently it was expected that conditions in Massachusetts Bay would be complicated, for tidal action and contrary winds, often of considerable force, might prove in themselves ample cause for confusion, even though other spawning grounds were not so located as to form an added disturbing influence.

As previously stated, the Plymouth grounds could be established easily as the principal production center for locally spawned eggs throughout the season. In Figure 6 (based on the results of eight trips) the large percentages of eggs in early cleavage stages found along the western shore from station 17 to station 8 indicate clearly the source of production during the winter and early spring. By comparing this figure with Figure 7 it will be seen that few late embryos remained along the western shore, the movement being either south into the arm of Cape Cod (stations 5, 6, 7 and 8) or directly across the bay in an easterly direction (stations 3, 2, 18, and 19). Drift-bottle experiments, which will be explained later, prove that both movements were taking place.

It was also interesting to find that, although storms apparently destroyed large quantities of eggs (see p. 268), the general distribution was not altered seriously. In spite of the particularly bad weather that had prevailed for several days before the fourth trip, Figure 12 shows a concentration of embryos about the Provincetown region and of newly-spawned eggs over the breeding grounds. Probably when the surface becomes disturbed the eggs tend to become distributed throughout the water mass and thus escape being forced along by the wind, like objects that remain at the surface. The distribution of stages during the fourth cruise was normal and quite typical of conditions existing during the winter and early spring.

The influence of haddock eggs first became noticeable on the eleventh cruise (April 7–8), when a considerable increase in the average number of eggs taken in Massachusetts Bay and also a noticeable change in the distribution of eggs in early cleavage were observed. Figure 13, based on the distribution of cleavage stages, shows for the first time large numbers of newly-spawned eggs in the outer parts of the bay. In fact, at stations 31 to 33 all of the eggs taken were in early cleavage,

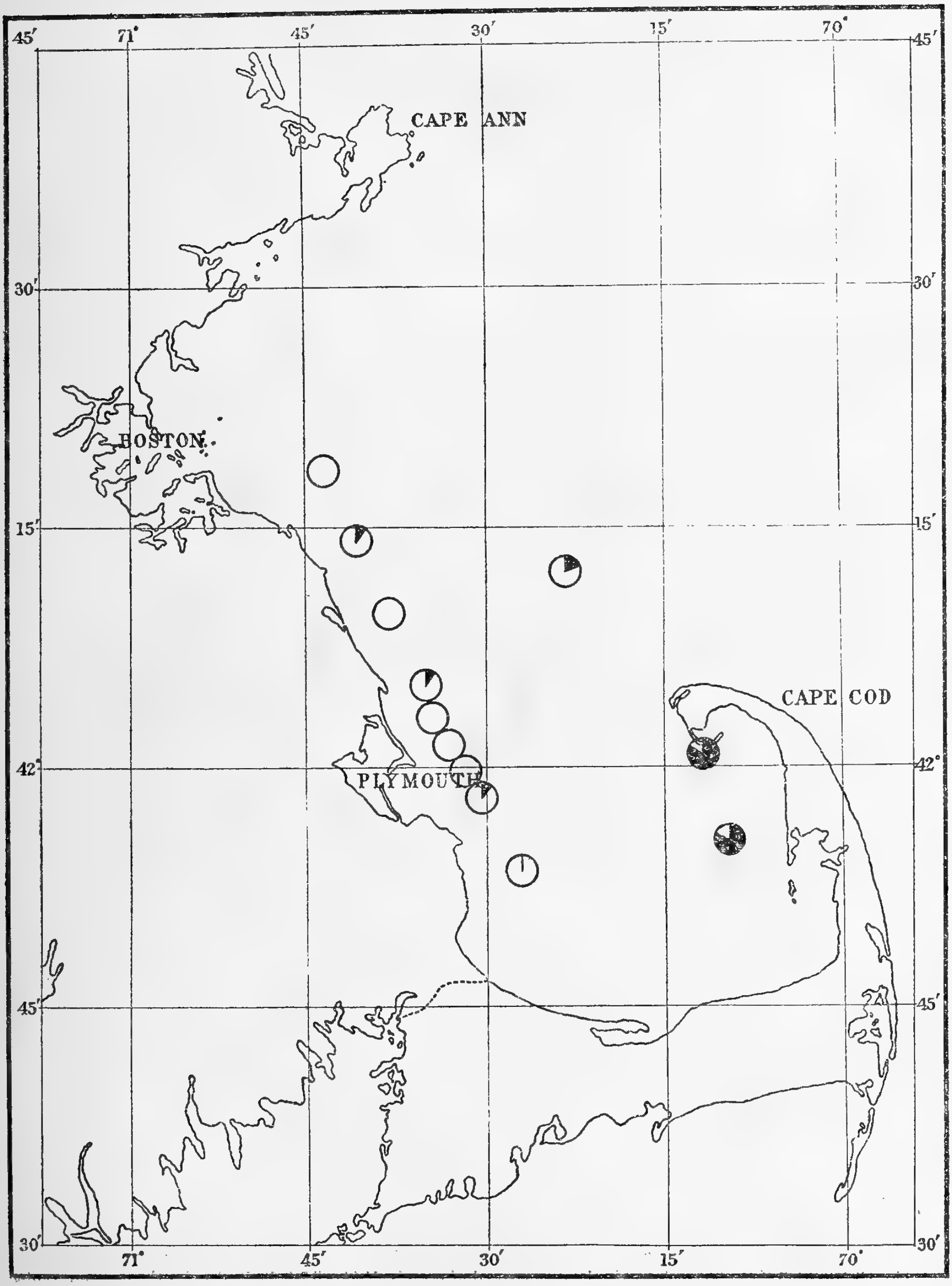

FIG. 12.—Percentage of cod eggs containing embryos during cruise 4 (December 22–23, 1924). Black sector indicates embryos

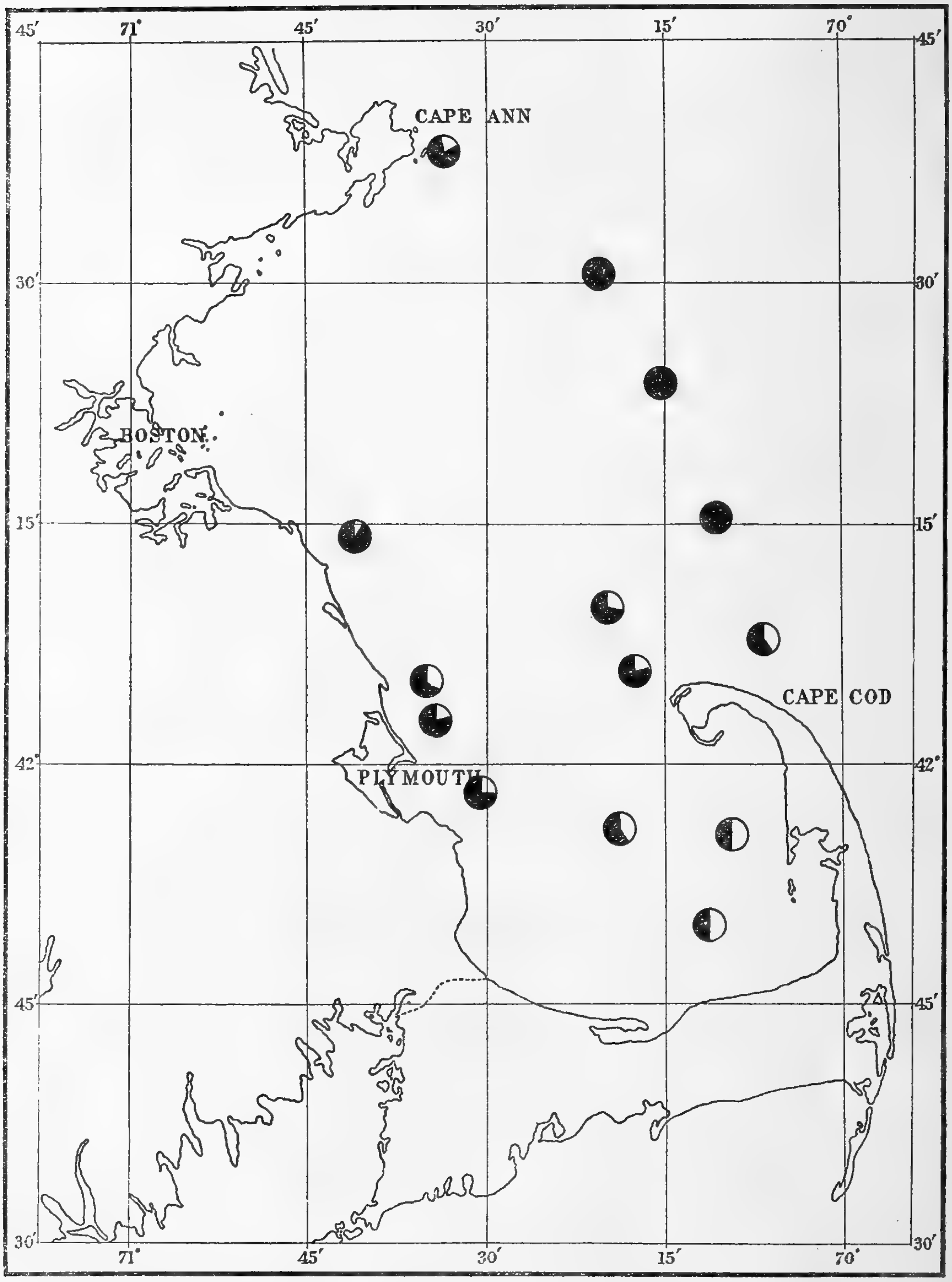

FIG. 13.—Distribution of cod-haddock eggs in cleavage stages during cruise 11 (April 7–8, 1925), showing the spawning center of the haddock in the outer part of the bay. Black sector indicates percentage of eggs in cleavage stages

As haddock do not spawn in the inner parts of the bay, the concentration of early cleavage stages on the Plymouth grounds indicates that considerable cod spawning still was taking place there.

Passing on to the late spring, Figure 8 again shows that spawning (haddock) was taking place along the Stellwagen Banks in the outer part of the bay and that there was still some production at Plymouth as well. There is also some indication that the influx of eggs into Massachusetts Bay from north of Cape Ann had begun, although less than 5 per cent of the eggs taken along the north shore were in cleavage stages.

DRIFT-BOTTLE EXPERIMENTS

For positive evidence of the set, drift bottles were placed in various parts of Massachusetts Bay in February and again in May. On the latter occasion the field was extended to include Ipswich. One hundred and forty-one bottles were set out during the year, and 49, or 34.7 per cent, were recovered.

Of 90 bottles set adrift on February 6 and 7, 18, or 20 per cent, were found within a few days along the inner arm of Cape Cod. (Table 6.) Four circled Cape Cod, one being taken 29 miles east-southeast of Stellwagen Bank,[2] two on the south shore of Nantucket, and one at Fire Island, N. Y. Four turned east, and of these, three appeared in Nova Scotian waters. One had started on a similar course when picked up 28 miles east-southeast of Cape Ann. On June 15, 1926, bottle No. 49 was reported from Lands End, Cornwall, England, where it had been picked up on the beach 494 days after starting its journey. In all, 27, or 30 per cent, of the bottles set adrift on this cruise were recovered.

TABLE 6.—*Record of recoveries. Bottles set adrift on February 6 and 7, 1925, in Massachusetts and Cape Cod Bays*

Bottle No.	Date set adrift	Locality where released: Latitude			Locality where released: Longitude			Date of recovery	Locality where recovered	Interval, days	Probable minimum distance covered, miles
	1925	°	′	″	°	′	″	1925			
25	Feb. 6	42	00	45	70	11	50	Feb. 11	Beach, Provincetown, Mass	5	4
26	do	42	00	45	70	11	50	Feb. 26	Pilgrim Heights, Provincetown	20	4
27	do	42	00	45	70	11	50	Feb. 12	East End Breakwater, Provincetown	6	4
28	do	41	58	12	70	10	48	Feb. 14	Pickett Wharf, Provincetown	8	6.5
29	do	41	58	12	70	10	48	Feb. 11	Provincetown	5	6.5
30	do	41	58	12	70	10	48	do	do	5	6.5
32	do	41	55	30	70	09	30	Feb. 12	Beach at Provincetown	6	9
33	do	41	55	30	70	09	30	Feb. 11	Beach at North Truro, Mass	5	6.5
34	do	41	52	18	70	10	30	do	East Harbor, Provincetown	5	11.5
35	do	41	52	18	70	10	30	do	Provincetown	5	12
36	do	41	52	18	70	10	30	Feb. 12	Smith's bathing beach, Mass	6	12
37	do	41	49	30	70	11	15	Feb. 11	Provincetown Harbor	5	16
38	do	41	49	30	70	11	15	Feb. 14	Beach at Provincetown	8	16
39	do	41	49	30	70	11	15	Feb. 12	Provincetown Harbor	6	16
40	do	41	52	27	70	15	24	Feb. 17	North Truro Beach	11	12
42	do	41	52	27	70	15	24	Feb. 22	Bay Shore, North Truro	16	11
43	do	41	56	00	70	18	30	Feb. 23	Beach Point, Provincetown Harbor	17	12
44	d	41	56	00	70	18	30	Feb. 18	Provincetown	12	12
22	do	42	03	18	70	14	42	July 4	Fire Island Coast Guard Station, N. Y	149	220
15	do	42	12	00	70	23	30	June 14	Near U. S. Naval Radio Station, Nantucket, Mass	128	88
74	Feb. 7	42	07	18	70	36	36	Feb. 16	29 miles east-southeast from Eastern Point, Stellwagen Bank.	9	49
78	do	42	09	30	70	38	15	June 30	2 miles east of Surfside, south shore, Nantucket	143	80
4	Feb. 6	42	19	00	70	36	05	Aug. 27	Meteghan, Digby County, Nova Scotia	202	237
82	Feb. 7	42	14	00	70	41	00	Aug. 5	2¼ miles south by west of Cape Sable, Shelburne County, Nova Scotia.	179	233
85	do	42	16	06	70	42	30	July 2	Cove near Freeport, Digby County, Nova Scotia	145	abt. 250
89	do	42	18	15	70	44	00	Feb. 17	28 miles east-southeast from Thatchers Island, Mass	10	38
								1926			
49	do	41	53	15	70	27	00	June 15	Beach at Lands End, Cornwall, England	494	----------

[2] There is some uncertainty about the location where this bottle was found.

Forty bottles were set out on May 20, 21, and 22, and 18, or 45 per cent, were returned (Table 7). The courses taken at this time differed considerably from those of February. Bottles placed along the north shore of Massachusetts Bay were carried either directly in by the tide or west with the set. Those from stations 17, 18A, and 32 moved south and grounded along the inner arm of the cape or on the outer tip about Race Point, but one of the bottles placed in Cape Cod [3] beached along the inner arm. Two (Nos. 114 and 117) circled westward and were picked up drifting off Plymouth. Two others (Nos. 112 and 113) from station 6A passed Race Point, but one grounded within a short distance on the outer side. The other joined the bottles from stations 34 and 14 and circled Cape Cod. Only in the latter group did the courses coincide with the movements of the bottles set out in February. Apparently none of the bottles liberated in Massachusetts Bay at this time moved east to Nova Scotian waters.

TABLE 7.—*Record of recoveries. Bottles set adrift on May 20, 21, and 22, 1925, in Massachusetts Bay*

Bottle No.	Date of release	Locality where released						Date of recovery	Locality where recovered	Interval, days
		Latitude			Longitude					
	1925	°	′	″	°	′	″	1925		
103	May 20	42	18	15	70	44	00	June 6	Dennisport, Mass	17
106	do	42	16	54	70	30	30	May 26	3 miles northwest of Race Point Light, Cape Cod	6
108	do	42	05	00	70	35	00	May 30	1¼ miles north of Pamet River, Coast Guard station, Cape Cod.	10
109	do	42	05	00	70	35	00	May 25	Coast Guard station, Provincetown, Mass	5
112	do	41	56	00	70	18	30	June 1	Race Point Coast Guard Station, Cape Cod	12
113	do	41	56	00	70	18	30	July 24	South Beach, Edgartown, Mass	65
114	do	41	49	30	70	11	15	May 29	6 miles east of Garnet Light, Plymouth, Mass	9
115	do	41	49	30	70	11	15	May 26	South Truro, Mass	6
117	do	41	55	30	70	11	15	May 31	5 miles west of Race Point	11
118	May 21	42	05	30	70	17	00	July 12	Nauset Beach, near Coast Guard station, Eastham, Mass	52
120	do	42	09	30	70	19	30	June 12	75 miles southeast and south from Cape Cod Light	22
126	do	42	23	30	70	15	30	May 27	1¼ miles west of Race Point Coast Guard Station	6
127	do	42	23	30	70	15	30	do	2 miles off Peaked Hill bar, Cape Cod	6
136	May 22	42	30	15	70	43	15	July 15	Marblehead Neck, Mass	54
137	do	42	30	15	70	43	15	June 1	Pea Island, Nahant, Mass	10
139	do	42	28	00	70	48	00	May 31	¼ mile east of Tinkers Island, Marblehead	9
140	do	42	24	15	70	52	15	May 27	Lynn Beach, Mass	5
141	do	42	24	15	70	52	15	May 28	Long Island, Boston Harbor, Mass	6

CURRENT MOVEMENTS IN FEBRUARY

Using the bottle drift of February, 1925, as the basis for determining the movements of cod eggs in early spring, it is possible to divide Massachusetts Bay into two general regions—southern and northern.

1. The southern region lies in Cape Cod Bay and comprises the area east of a line extending from Race Point, on the tip of Cape Cod, to the canal. From within this zone no bottles are known to have escaped the bay; all those reported fetched up along the inner arm or entered Provincetown Harbor. Stations 5, 6, 6A, and the drift-bottle stations between these points were included in the region.

2. The northern region consists of that part of Massachusetts Bay lying north and west of the southern area. All recovered bottles placed within this area in February drifted in an easterly direction out of the bay. This region may, in turn, itself be divided into two parts, for after passing beyond the tip of Cape Cod, the current divides into two branches, one branch turning west along the outer side of the cape, the other east to continue the anticlockwise drift around the Gulf of Maine.

[3] Portion of Massachusetts Bay bounded by Cape Cod.

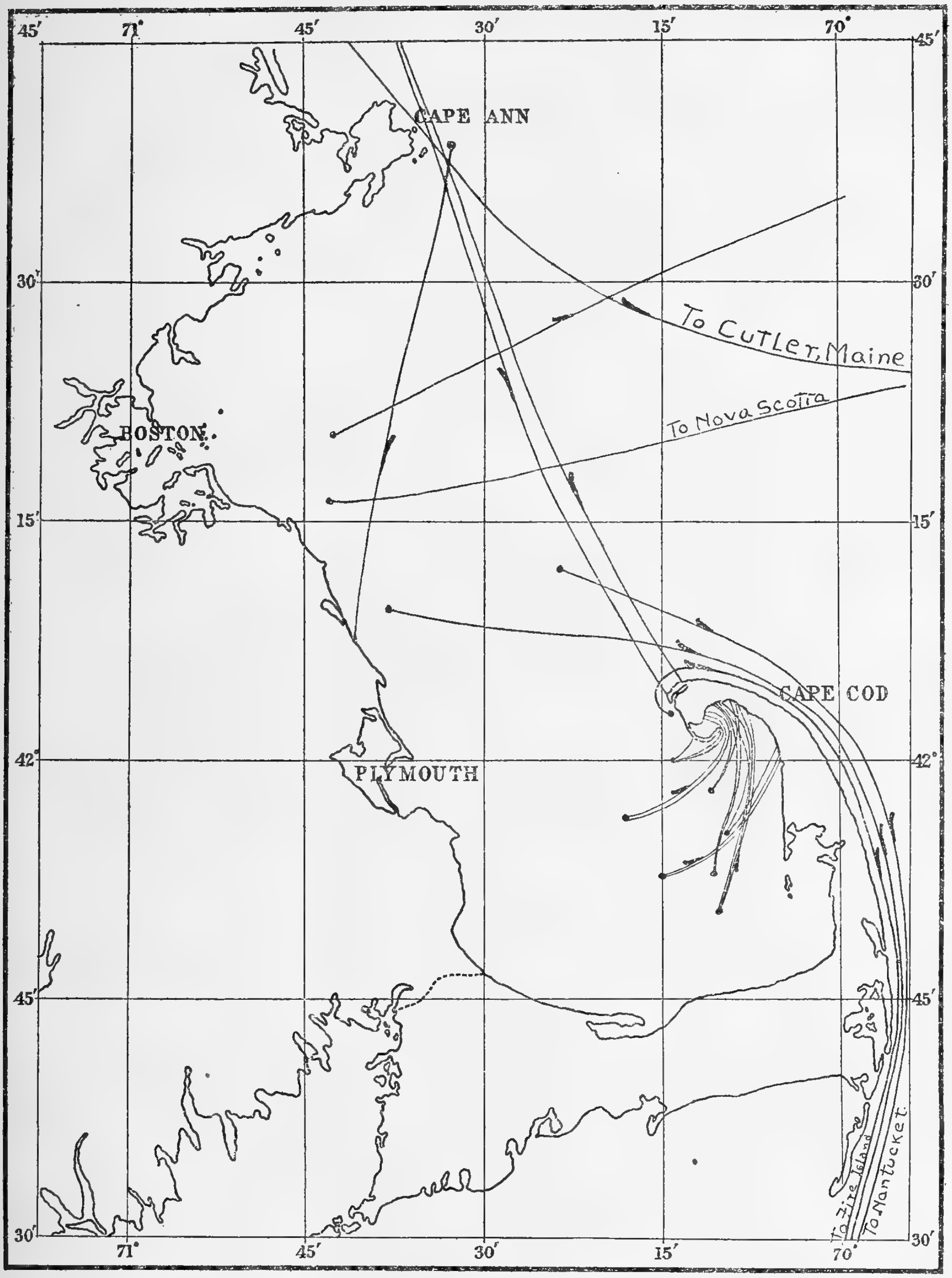

FIG. 14.—Assumed drifts of recovered bottles set out in Massachusetts Bay, February 6-7, and in Ipswich Bay, April 7, 1925, place of release

A line extending east from a point midway between stations 15 and 16 (about latitudes 42° 10′ N.) would divide these two branches. All bottles set out in the southern part of this region turned south after leaving Massachusetts Bay and were recovered either along the outer side of Cape Cod or at Nantucket. Stations 9 to 15, with the inserted drift-bottle stations, are in this section.

Bottles in the northern part turned to the east. This area includes stations 2, 16 to 19, and inserted drift-bottle stations between stations 16 and 19.

RATE OF DRIFT IN FEBRUARY, 1925

The bottle records also throw important light upon the rate of drift. Taken by sections, the February records indicate that the average rate of drift in the southern region was 1.5 nautical miles per day. This slow-moving drift about the inner arm of Cape Cod represents a minor lateral branch of the main current. In the northern region the average rate of the set leaving Massachusetts Bay, as shown by the two bottles found drifting, was 4.4 miles per day. Bottle No. 74, set out in the northern section, had taken the easterly course and averaged 5.4 miles per day for nine days. Bottle No. 89, from the southern part of this region, drifted in the opposite direction at a rate of 3.5 miles per day. Either these two branches later slackened their speed considerably, the route was circuitous, or the bottles remained for some time before being found, because the three that reached Nova Scotia show an average of only 1.36 miles per day and the two grounding at Nantucket, 0.62 mile per day. The average drift out of Massachusetts Bay of approximately 4.5 miles per day agrees very well with Mavor's (1922) records for 1919, when 11 bottles traveled from the Bay of Fundy to Massachusetts Bay at an average rate of at least 4 miles per day.

Applying the drift-bottle data to egg movements, it will be seen that the spawning grounds in Massachusetts Bay are included almost entirely in the northern region. This suggests that the bulk of the eggs produced during the winter and early spring would follow the course of the drift bottles directly out of the bay. Those taken along the inner arm in Cape Cod Bay (figs. 7 and 12) probably represent the output of a very small fraction of the grounds—the southern extremity. The drift-bottle experiments, therefore, indicate that during the height of the season (January and February) by far the greater part of the eggs produced on the Plymouth grounds do not even circle the bay before entering the coastal waters but drift directly out at a rate that may exceed 4 miles per day.

DRIFT-BOTTLE RESULTS IN MAY

By May, 1925, the general set in Massachusetts Bay had become considerably altered (fig. 15). The increased amount of water entering from the Gulf of Maine caused the direction of the set to change, so that, instead of turning west and following around the shore line of the bay, it was forced directly across the entrance in a southerly direction. During the winter and early spring the entering current probably circles around the inner margin of the bay. The general sweep of the drift in May is clearly indicated by the movement of bottles from stations 18A and 32 (fig. 15). In February these bottles would have been directly in the path of the easterly drift, but now they were carried south to the tip of Cape Cod, where two grounded. A third barely missed the cape and was found drifting 2 miles off Peaked Hill Bar.

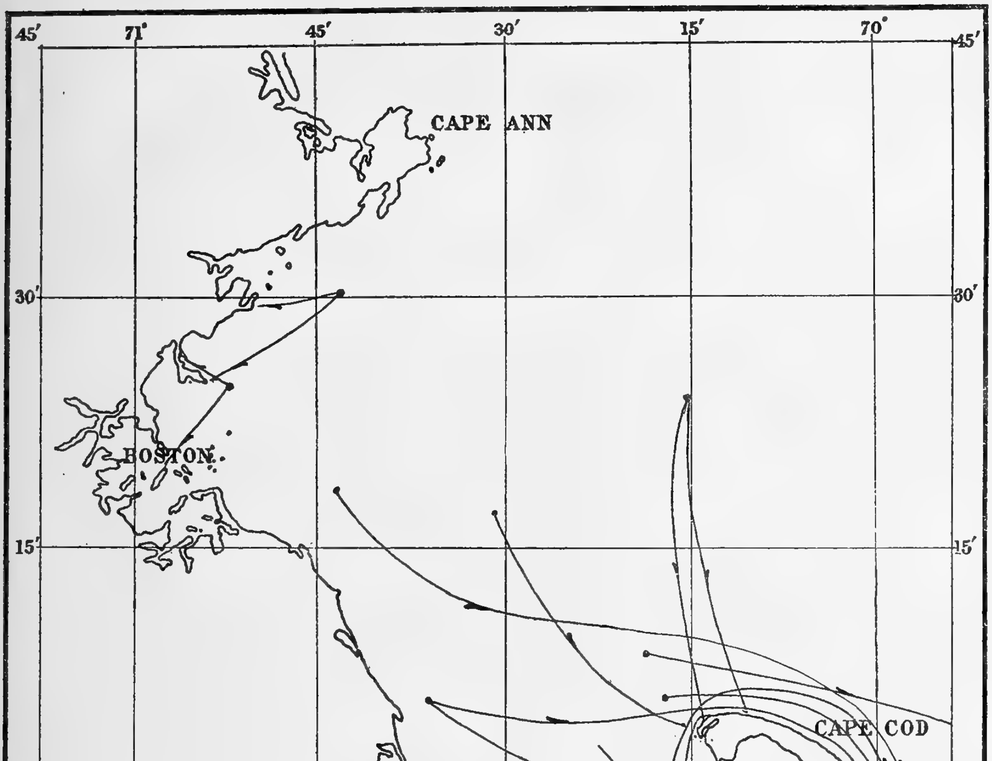

Fig. 15.—Assumed drifts of representative bottles set out in Massachusetts Bay, May 20–22, 1925, place of release

Mavor's bottles in 1919 showed a similar movement across the entrance of the bay, three passing the tip and stranding along the outer side of the cape. However, although the main body of the water mass escapes Massachusetts Bay, bottles placed on the north side indicate that a definite drift passes in along the shore. This set was noted previously in April by the course of bottle No. 99 from Ipswich Bay to the Brant Rock.

There is considerable uncertainty about the movements of the drift in Cape Cod Bay in May. In February the presence of a uniform anticlockwise set was evidenced clearly by the fact that all recovered bottles not grounding along the way passed directly into Provincetown Harbor. However, none of those set out in May reached Provincetown; in fact, but one stranded in the bay. Figure 15 gives the possible movements of bottles at this time. It will be seen that, although the general movements of all bottles placed in Cape Cod Bay were northerly, the exact courses are rather confusing.

One would hardly expect that bottle No. 117 would require 11 days to travel 12 miles and bottle No. 114, placed out on the same day, 9 days to travel 18 miles. The fact that these two bottles passed to the west, directly across the path of two others set out at virtually the same time and which rounded the cape in the opposite direction, is further evidence of the complexity of the set in Cape Cod Bay at this time. Again, in view of the courses taken by the two bottles from station 14 and those from stations 6 and 7, the course of bottle No. 103 to Dennisport Beach is not clear. Therefore, after the beginning of the spring floods, it is not possible to retain the regions into which the bay was divided on the basis of February returns.

Bottles placed in Cape Cod Bay in May drifted in a northerly direction and joined the easterly set out of Massachusetts Bay. Thus, at this time the eggs from all the grounds would drift out. The two sections of the northern region, in turn, could not be distinguished because the movement of all bottles leaving the bay was southerly. That a branch later may pass to the east is illustrated by subsequent observations. As far as is known, none of the bottles set out in May, 1925, by the *Fish Hawk* took this course; but part of a line placed in Cape Cod Bay on April 19, 1926 (Bigelow, 1927), were recovered in Nova Scotian waters and part at Nantucket. This indicates that, even though the dominant drift across the mouth of Massachusetts Bay at this time is southerly, eggs spawned on the Ipswich and Plymouth grounds in the late spring may be transported to either Georges Banks or Nantucket Shoals.

In discussing the results of the April, 1926, series, Bigelow (1927) speaks of a "strong or general tendency southward, across the mouth of Massachusetts Bay and so down past Cape Cod, recalling the drifts of bottles from Ipswich Bay and out of Massachusetts Bay the spring before. All that is needed to make the parallel between the two years complete is Nova Scotian returns for the series of 1926." However, no matter how the currents set in Cape Cod Bay in the late spring, the conditions are equally unfavorable for retaining cod eggs; for, as indicated by the five recovered bottles set out in this region, all not destroyed are carried out.

RATE OF DRIFT IN MAY

Four bottles set adrift on the May cruise were recovered before grounding. The average rate of Nos. 126, 127, and 106 (the courses of which are obvious) was 3 miles per day. The rate of No. 109 from station 14 was 3.4 miles, while the rate

of No. 108, from the same station, was 2.9 miles. It is hardly justifiable to give the average rate of all bottles for this cruise, because the courses taken by those within Cape Cod Bay are not definitely known, and such bottles as Nos. 112 and 118 evidently had been on the beach for some time.

The returns from the bottles placed along the north shore of the bay (stations 36 to 38) proved rather surprising. The general courses taken agreed with expectations, being carried either directly inshore by the tide or drifting westward with the set of the current. (Nos. 136 to 141.) However, it was not expected that the rates would be so slow. It is hardly probable that they could have grounded at such widely separated places and, after lying on the shore for several days, all be found within such a short period. No. 136 evidently had been ashore for some time when recovered, but the other four bottles set out on May 22 were recovered on May 27, 28, 31, and June 1. The average rate of Nos. 137 and 141, which were carried west, was 0.92 mile per day. Bottle No. 120, found drifting 75 miles off Highland Light, had traveled a minimum distance of 91 miles at a rate of 4.1 miles per day.

To summarize the evidence shown by bottle movements in Massachusetts Bay, the greater part of the cod eggs spawned in winter and early spring probably move east directly across the bay at a rate of 3 to 4 miles per day. In the late spring the drift certainly is not diminished and, as shown by bottle No. 120, may retain a rate of 4 miles for at least 90 miles.

IPSWICH BAY

The spawning grounds in Ipswich Bay, situated just north of Cape Ann, are in a favorable position to form a source of supply for Massachusetts Bay, for they lie in the path of the westerly drift. Regarding this drift, Bigelow and Welsh (1925, p. 75) state that "fish eggs and larvæ, and for that matter every member of the plankton, animal or vegetable, tend to follow the same peripheral migration zone as do the immigrants that enter the eastern side of the gulf in the upper 50 meters. Only such buoyant eggs as are spawned among the islands, in bays, or close in alongshore (as most of the cunners are) are likely to escape this dominant set."

Three trips were made to the regions lying between the Isle of Shoals and Cape Ann. (Fig. 5.) The data obtained from these few observations are hardly sufficient to explain the conditions existing throughout the season but clearly indicate the movement of the eggs. At the time of the first trip (March 12) considerable spawning was taking place, and an average of 64 cod-haddock eggs was obtained at each of five stations. (See Table 5.) On March 25 the average rose to 117 and on April 7 to 127 eggs per station.

The stations were arranged in two parallel lines (fig. 5), and on every trip the number of eggs taken on the western (inshore) line was by far the greatest, thereby indicating an alongshore and not a seaward drift. The following table, giving the quantitative distribution of eggs on trip 10, illustrates this movement. The two lines were only about 2 miles apart.

TABLE 8

Station	Western line: Percentage in cleavage stages	Western line: Number of eggs	Station	Eastern line: Percentage in cleavage stages	Eastern line: Number of eggs
28	100	490	27	100	18
26	100	88	25	100	39
24	100	154	23	100	2
22	100	142	21	100	5

The general movement of the set is shown further by the distribution of incubation stages. As the table indicates, all of the eggs taken on trip 10 were in cleavage stages. Figure 16 gives the combined results of the three trips to the Ipswich grounds. It will be seen that in Ipswich Bay the cod eggs drift out at even earlier stages than in Massachusetts Bay, for of 1,767 taken north of Cape Ann, only 1 contained a late embryo. This appeared at station 22, the most southerly station on the inner line.

Whither these eggs drift is a question. Appearing during the increased spring set, virtually all of them pass south across the entrance of Massachusetts Bay, and those that do enter probably do not penetrate far but soon are carried out again

TABLE 9.—*Record of recoveries of 11 bottles set adrift on April 7, 1925, in Ipswich Bay*

Released: Bottle No.	Station	Time, a. m.	Latitude (north) ° ′ ″	Longitude (west) ° ′ ″	Recovered: Locality	Date	Interval, days
95	23	3.20	42 49 30	70 40 00	¼ mile west of Race Point, Cape Cod	Apr. 21	14
96	23	3.20	42 49 30	70 40 00	¼ mile southeast of Race Point	Apr. 24	17
97	21	4.30	42 46 00	70 40 00	2 miles off Cutler, Me.	July 21	105
99	29	6.10	42 38 00	70 33 00	2 miles north of Brant Rock Coast Guard Station, Mass.	Apr. 29	22

DRIFT-BOTTLE RECORDS

Eleven bottles were placed in Ipswich Bay on April 7, 1925, and of these, four have been recovered (Table 9). One entered Massachusetts Bay and was found near the Brant Rock Coast Guard Station. Two moved south across the entrance and stranded near Cape Race, and one drifted around the gulf to Cutler, Me., near the western entrance of the Bay of Fundy. The movements of these bottles reflect the nature of the currents at this time. In passing Cape Ann, two were carried in the main set directly across the entrance of Massachusetts Bay to the tip of Cape Cod. Another, passing outside of Cape Cod, followed the counterclockwise set around the Gulf of Maine, probably traveling along the eastern part of Georges Bank. The route taken by bottle No. 99 indicates that a branch of the current, passing Cape Ann, turns west and follows the shore line into Massachusetts Bay. Any statement regarding the migrations of eggs from Ipswich Bay in the spring must, therefore, be merely speculative. However, it is possible that, like the winter and early spring eggs from Plymouth, some of which, after leaving Massachusetts Bay, appear to go east and others west, many of the Ipswich eggs may deflect to the east after passing south of the Cape and, if the movement happens to be seaward (bottle No. 120), supply Georges Bank as well as Nantucket Shoals.

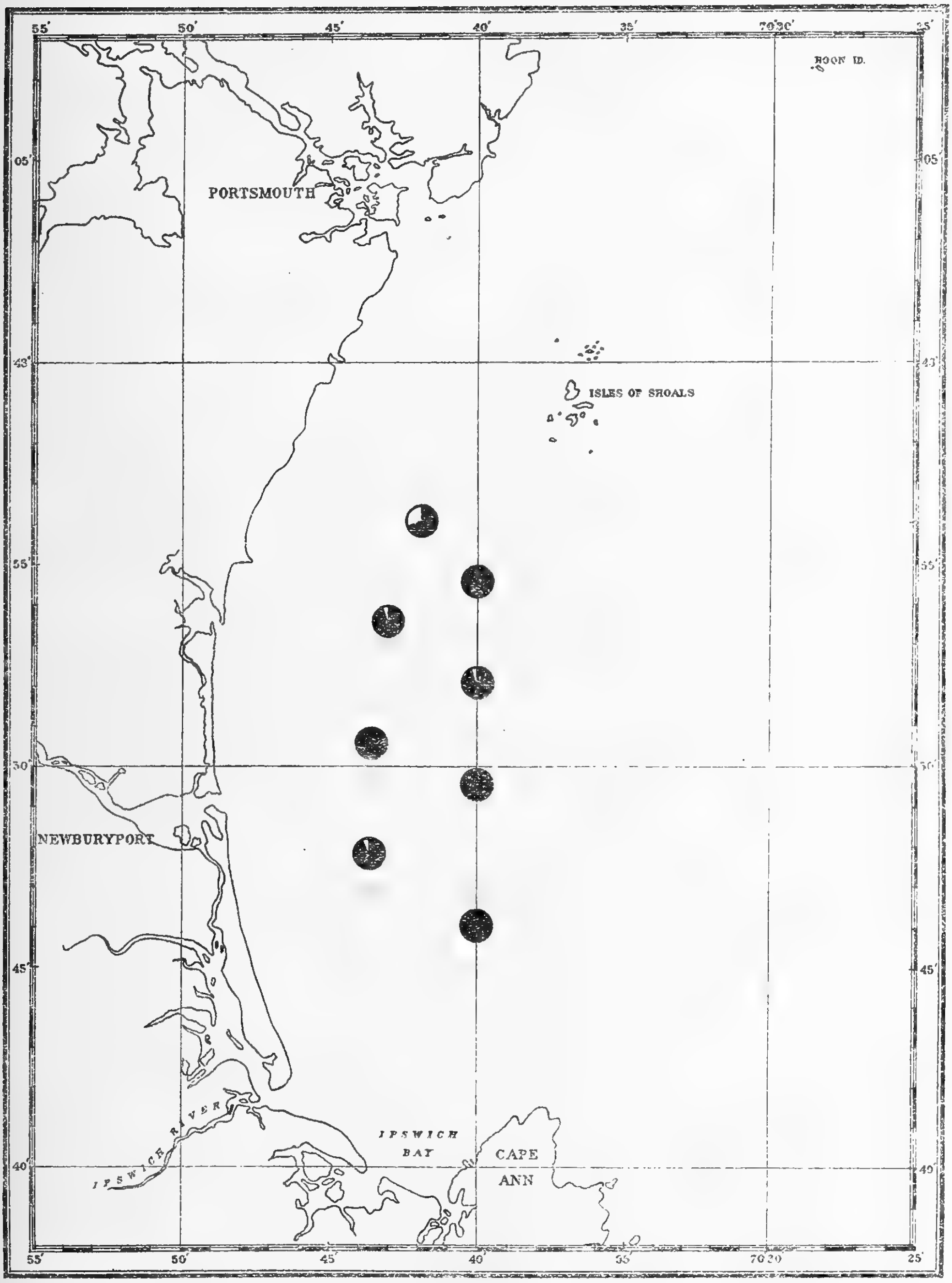

FIG. 16.—Percentage of cod-haddock eggs in cleavage stages in Ipswich Bay during cruises 9 to 12, inclusive. Black secto indicates eggs in cleavage stages

GENERAL DISCUSSION

In attempting to account for the disappearance of cod eggs and the absence of fry in Massachusetts Bay we must take into account the possibility that the eggs perish before hatching. Possibly the absence of fry may be attributed to a combination of two or even more factors. There are several ways in which the eggs and larvæ may be destroyed:

1. *Storms.*—Without doubt storms destroy not only large numbers of pelagic eggs and fry, but immense numbers of other planktonic animals as well. As previously stated, Tables 4 and 5 show clearly the disastrous effects of the storms preceding trips 4 and 6. There can be little question that the decline in the number of cod eggs taken on trip 6, from 697 (the number taken on trip 5) to 236, and the striking reduction in the number of pollock eggs, from 781 on trip 5 to 2 on trip 6, resulted from unfavorable weather. The fact that the sudden drops in numbers in the middle of the season coincided in each case with bad weather and no other apparent change in the physical conditions affords added evidence of destruction by storms. However, storms in themselves are not sufficient to explain how fry can be completely destroyed in a protected area like Massachusetts Bay and yet survive the terrific gales that sweep across such exposed breeding grounds as Georges Banks and the Grand Banks. Were storms the sole destructive agent, at least a small percentage of the large number of late-embryo stages taken in the Provincetown region would be expected to hatch.

2. *Unsuitable physical conditions.*—The possibility that wave action (which in water so shoal would extend from the surface to the bottom) might so disturb the fish that they would stop spawning is not applicable in this case, because, although it might account for the absence of newly spawned eggs, it would not explain the disappearance of later development stages as well. Other physical conditions, such as temperature and density, were normal in 1924–25 and rarely, if ever, approached limits critical to cod eggs.

3. *Food.*—During the late winter and early spring there is a scarcity of zoöplankton in the Gulf of Maine, that present being dominated by adult animals (calanids and Sagittæ) too large to serve as food for early fry. About the time of the spring diatom maximum in March and early April, the reproduction season of the calanids occurs, and by April the water teems with the young. As copepod nauplii form a favorate diet of cod larvæ, there is no lack of food in the late spring. It is reasonable to conclude, therefore, that although food may prove important in some localities, it is obviously not the determining factor in Massachusetts Bay, for the cod-spawning season at Plymouth extends from the period of scanty zoöplankton right through the vernal reproduction period of copepods, and yet no young cod appeared at any time. The eggs vanished just as completely during the time when food was plentiful as when it was scarce. The zoöplankton scarcity in Massachusetts Bay is a short-time one and probably does not affect seriously the natural economy of the region.

4. *Enemies.*—The destruction of fry, and possibly eggs, by enemies in the plankton is probably an important limiting factor. Recent investigators have emphasized the necessity of considering enemies of this sort. Dannevig (1919) found that cod eggs disappear from the spawning grounds in the waters about Lofoten

and Finmark and, although admitting that currents are important as transporting agents, believes that the greatest attention should be paid to the wastage caused by other animals. Bigelow (1926) has also called attention to the importance of enemies in limiting the numbers of fish. In 1925 *Tima formosa*, a large hydromedusa, was everywhere abundant during the height of the cod season at Plymouth, and many of the specimens taken contained one or more young fishes of various species. One was taken with six postlarval herring entangled by its manubrium. As these fish were 40 millimeters in length and capable of rapid movement, the helpless larvæ of such species as the cod must fall an easy prey and be destroyed in large numbers. *Beröe cucumis*, another arch enemy of young fish, also was abundant. There can be little doubt that enemies of this type could destroy large quantities of fish fry; but here, again, contradictory evidence is encountered, for larvæ of pollock were at times rather numerous, even about Plymouth, although this species spawns in very limited numbers in the inner parts of the bay. Were enemies the controlling factor, larval cod could hardly be completely destroyed at all times while specimens of such a closely related species survive in abundance. The following is a record of pollock larvæ taken on the Plymouth grounds on trip 1.

Station	Pollock larvæ
8	35
9	29
10	68
11	42
12	2
17	5

Other species of larval fishes, particularly sand eels, also were abundant at times. On trips 5 to 12 sand eels swarmed along the inner arm of Massachusetts Bay. At station 22 (trip 9) 375 appeared in a single haul. The distribution of this species is not exactly comparable to that of the cod and pollock, because, having demersal eggs, the young hatch and enter the surface waters in precisely the same spot where the eggs were deposited; but it is mentioned to show another species, the young of which escapes annihilation by enemies.

5. Drift.—The evidence of drift is overwhelming. In several other localities investigators have found that ocean currents play an important part in the distribution of cod eggs. Schmidt (1909) studied the drift of eggs about Iceland; Hjort (1914) and Damas (1909) reported similar migrations off Norway, and Petersen (1892) in Danish waters. Dannevig (1919) found that cod eggs disappear with greatest rapidity in the outer waters off Lofoten and Finmarken. An interesting account of the movements of eggs in English waters also has been published by Graham (1925).

In Massachusetts Bay both the drift bottles and the charts on egg distribution show very well the general movement of the circulatory drift in the bay.

Special attention was devoted to the incubation period of cod eggs as affected by fluctuating water temperature and the consequent variations in the interval during which they would drift before hatching. These data were then applied with the rates, as indicated by bottle drifts, to determine the probable distance that eggs leaving Massachusetts Bay would be carried before hatching.

The following table gives the incubation periods of eight collections of cod eggs at the Woods Hole hatchery, the first seven of which were subjected to the normal winter cooling of the water:[4]

TABLE 10

Date received	Number of eggs received	Number good after 24 hours	Date hatched	Number of eggs hatched	Incubation period, days	Average temperature, ° C.
Nov. 10, 1925	426,000	289,000	Nov. 22, 1925	184,000	13	8.5
Nov. 11, 1925	994,000	910,000	do	794,000	12	8.56
Nov. 21, 1925	11,361,000	10,092,000	Dec. 4, 1925	9,176,000	14	6.8
Nov 23, 1925	15,414,000	14,235,000	Dec. 6, 1925	12,387,000	14	6.67
Nov 28, 1925	11,598,000	10,593,000	Dec. 11, 1925	8,573,000	14	6.0
Dec. 9, 1925	6,114,000	5,684,000	Dec. 28, 1925	4,947,000	20	2.83
Dec. 15, 1925	3,553,000	3,290,000	Jan. 5, 1926	2,553,000	22	1.56
Jan. 1, 1926	3,532,000	3,225,000	Jan. 19, 1926	1,613,000	19	3.33

These data were prepared to serve as a comparison with the records of other observers made on eggs maintained at constant temperatures. The collection received on January 1, 1926, after the water had been raised artificially to a constant temperature of 3.33° C., is included as a check and compares very well with the following records of Ryder, Hensen, Earll, Bigelow, and Welsh.

TABLE 11

Incubation period, days	Temperature, ° C.	Authority	Incubation period, days	Temperature, ° C.	Authority
10-11	8.33	Bigelow and Welsh.	20	3.00	Hensen.
13	7.22	Earll.	20-23	3.33-3.89	Bigelow and Welsh.
13	7.50	Hensen.	21	3.33	U. S. Fisheries Manual.
14	6.11	U. S. Fisheries Manual.	24	2.20	Hensen.
14-15	6.11	Bigelow and Welsh.	34	.50	Do.
16	5.00	Hensen.	40 or more	.00	Bigelow and Welsh.
20	3.33	Ryder.	50	−1.20	Hensen.

By comparing Tables 10 and 11 it will be seen that, in determining the length of an incubation period during the fall cooling of the water, the average temperature may be used. Thus, on November 21 eggs hatched in 14 days at an average temperature of 6.8° C., which compares very well with the records of Bigelow and Welsh and the United States Fisheries Manual for eggs maintained at a constant temperature of 6.11° C. Again, on December 9, eggs hatched in 20 days at an average temperature of 2.83° C. as compared to 3° C. given by Hensen for a similar period. In the light of these data it was possible to determine the approximate incubation period at the time of each cruise. Using the range indicated by the mean surface and bottom temperatures, the following results were obtained:

TABLE 12

Trip	Mean surface temperature, ° C.	Mean bottom temperature, ° C.	Approximate incubation period, days	Date 1924-25
1	6.14	6.13	14-15	Dec. 3.
2	6.20	6.25	14-15	Dec. 9-11.
3	5.02	5.46	15	Dec. 16-17.
4	4.30	4.75	16-17	Dec. 22-23.
5	2.54	2.60	22	Jan. 6-8.
6	.75	.95	30	Feb. 6-7.
7	1.65	1.68	26-28	Feb. 24-25.
8	2.00	1.89	24-25	Mar. 10.
11	4.59	3.40	17-20	Apr. 7-8.
12	5.27	4.02	14½-17	Apr. 21.
13	8.89	4.57	9-17	May 20-22.

[4] Eggs obtained from tank fishes.

During the early part of the spawning season at Plymouth, and again near the end of the season, the eggs drift for 14 to 17 days. However, in the coldest months (February, in 1925) the drift may range from 24 to 30 days. Taking 4 miles per day as the average rate at which eggs are carried out of the bay, in December they might travel 56 to 68 miles before hatching; in February they would travel 104 to 120 miles, and it must be remembered that after leaving the egg young cod drift from two to two and one-half months before seeking the bottom. It is quite probable, therefore, that each year fry produced in Massachusetts Bay and the inshore waters north of Cape Ann may be distributed over almost all of the offshore banks. In fact, it is conceivable that some circle the gulf and are carried in on the east side by the same drift that carries the eggs out on the west. Nantucket Shoals, Georges Banks, and the grounds in the Gulf of Maine may all benefit by this dispersal, but to what extent is a question.

It is possible that the presence of the young cod that each year enter the shore waters about Woods Hole in company with large numbers of pollock may be explainable on this basis. Pollock, as far as is known, do not spawn south of the cape, but the extensive breeding grounds on Stellwagen Banks lie in the path of the southerly set, and the eggs could easily be carried south to Vineyard Sound. It is also possible that of the small cod, 3 to 4 inches in length, found in abundance on Georges Bank, in August, 1926, some originated in the inshore waters. Until this work has been extended to cover the outer waters, these suggestions must remain mere possibilities.

We can speak with more confidence about conditions in the inshore waters. There is reason to believe that the cod stock of the coastal belt of the Gulf of Maine is not self-supporting, so that were it not for constant immigration from the outer waters the supply would be exhausted. It is possible that the same drift that carries the eggs out of Massachusetts Bay may carry young fish in from the offshore banks. The large numbers of young cod, 12 to 14 inches in length, found at certain places along the coast of Maine suggest this.

How important Massachusetts Bay is as a production center has not yet been determined. Its value as a nursery is no greater than that of any other equal sector of the coastal belt, but as a source of supply for offshore banks it may prove of significance. To estimate this, it will be necessary to trace the courses of the eggs from the bay, determining where they hatch, the food and enemies of the fry, and their fate. Although it has not been possible, on these 13 cruises, to find solutions to all of the problems involved in a determination of the value of Massachusetts Bay as a production center, it is hoped that it will form the beginning of a much more extended investigation of (1) the outer banks and (2) the fate of the eggs that pass beyond the confines of the bay.

In discussing the cod Professor Baird long ago stated that deep-sea fisheries depleted in any particular locality will not be restored; no fish will come from surrounding localities to take the vacant place (Prince, 1909). The second statement has been borne out to some extent by recent cod-tagging experiments, which indicate that in places schools of cod are confined to certain definite areas and do not migrate up and down the coast in a haphazard manner. However, whether or not the depleted areas would be restored will depend not necessarily on immigration by adults, but upon the ultimate goal of the millions of tiny eggs and fry that drift out of such areas

as Massachusetts Bay. If such a drift should bring larvæ to a depleted area, restoration of the cod stock there might be rapid. For example, although the adult cod from the region of Nantucket Shoals apparently do not migrate north of Cape Cod, many of them may have originated from eggs transported from the Gulf of Maine. Therefore, if Prince (1909) were correct in his view that the restoration would be a matter of a long time, it would be necessary to assume that of the millions of fry that Hjort (1914) found to be carried sometimes for hundreds of miles, being sown over the coastal banks, few, if any, survive, and such a condition is inconceivable.

SUMMARY

1. Cod spawn at a wide range of temperature in Massachusetts Bay. Considerable spawning was taking place on November 12, 1924, at a time when the surface temperature had fallen to only 10.1° C. At Plymouth the height of production continued through the coldest season (0° C. or even lower in places). In Norway it has been found that spawning cod are limited strictly to a water layer between 4° C. and 6° C.[5] Spawning in the bay continued throughout April, but apparently had ceased by May 20, 1925. These grounds could be established easily as the production center for locally spawned eggs throughout the season.

2. The results indicate clearly that a very definite and constant counterclockwise drift carries cod eggs spawned in Massachusetts Bay out before they hatch. Throughout the breeding season eggs were found in abundance, particularly about the Plymouth grounds, but the collections of 14 cruises failed to yield a single young cod.

Some of the drift bottles set out to indicate the rate and direction of the drift fetched up on the inner arm of Cape Cod. Those escaping Massachusetts Bay divided into two branches, one of which completed the circle about the margin of the Gulf of Maine and appeared on the Nova Scotia coast. Those turning south passed into the region about Nantucket. One apparently drifted farther to the eastward and was carried in the Gulf Stream to Lands End, Cornwall, England, where it was recovered more than a year later.

Investigations carried on in Ipswich Bay (an important adjacent spawning ground to the north) yielded similar results, showing that here the eggs are carried east or south beyond Cape Ann at even earlier stages than in Massachusetts Bay.

There is evidence that some of the eggs entering Massachusetts Bay from the east in the late spring hatch before leaving the bay, but this is of minor importance, for the fry drift for two to two and one-half months, and the same current that carries them in from the east transports them out again on the south. They are merely transients.

We must therefore conclude that local production in Massachusetts Bay does not maintain the inshore stock, and were it not for constant immigration from the outer waters the supply would be exhausted. As a nursery, its value can be no greater than that of any other equal sector of the coastal belt, but as a source of supply for offshore banks it may prove of significance. This will depend upon the ultimate destination of the eggs passing beyond Cape Cod. It is probable that Nantucket Shoals, Georges Banks, and the grounds in the Gulf of Maine may all benefit by this dispersal.

[5] Procès-Verbaux, Conseil Permanent International pour l'Exploration de la Mer, Vol. XXXVIII, September, 1925, p. 82.

SIZE OF COD EGGS

In the course of the investigation many interesting observations were made on allied problems, which, for the most part, will have to be treated separately later. However, because of its possible application in future surveys of this type, it may be well to include a brief report on the effect of temperature on the size of cod eggs.

In making a study of production centers where the local stock is supplemented each year by contributions in the form of eggs and pelagic fry from other sources it will be highly desirable if one can determine in any one area the quantity of eggs supplied from other spawning centers and their relative importance compared with local production. If the temperature at the time of fertilization affects the size of cod eggs, and if the physical conditions in two spawning centers are sufficiently different, then it is quite probable that locally spawned eggs in one of these two areas may be distinguished by measurement from immigrants from the other. For example, on the Grand Banks the cod spawn in summer at a time when the temperature of the shallow banks water has risen considerably above that of the Labrador current. If eggs produced farther north and carried south to the banks can be distinguished, through their size, it may throw important light on the problem of whether the cod stock of the Grand Banks is self-supporting or, if not, to what extent it is dependent upon contributions from other sources.

I first noticed the variation in cod eggs collected in the region of the Grand Banks on June 5 to 17, 1924. There was a very striking difference between those from the warm, shallow water over the bank and those from the cold Arctic current. The average size of the banks eggs, based on measurements of about 500 eggs, was 1.28 millimeters, while at station 3, in the Labrador current, the average was 1.42 millimeters. The following table gives the results for each station:

TABLE 13

Date, 1924	Station	Average	Smallest	Largest	Number measured
		Millimeters	*Millimeters*	*Millimeters*	
June 5	1	1.31	1.10	1.38	240
June 7	2	1.27	1.17	1.32	5
Do	3	1.42	1.35	1.55	16
June 12	4	1.27	1.20	1.50	9
June 13	5	1.24	1.20	1.27	7
June 15	6	1.28	1.15	1.40	65
June 16	7	1.29	1.17	1.40	107
June 17	8	1.30	1.19	1.40	56

The eggs were found to average between 1.2 millimeters and 1.3 millimeters everywhere except at No. 3, the most northerly station (approximately 390 miles north of the tip of the Grand Banks), where the surprising average of 1.42 millimeters was found, no eggs being less than 1.35 millimeters. The total absence of cleavage stages at this station (the earliest eggs having the embryo well developed) indicates that they may have been carried for a long distance and belong to an entirely different race of fish, although I do not think the latter condition probable. The rate of flow of the Labrador current at this point, the low temperature, and the number of planktonic forms occurring here and at no other station, tend to substantiate the former possibility. *Metridia longa* and *Calanus hyperboreas*, true arctic

forms, were very abundant at station 3, but totally absent elsewhere. A similar variation was found in Massachusetts Bay eggs at various seasons. The average size increased during the cold winter months and declined as the water warmed in the spring.

TABLE 14.—*Cod eggs from Massachusetts Bay*

Date	Average size of 50 eggs	Date	Average size of 50 eggs
	Millimeters		*Millimeters*
Dec. 11, 1924	1.458	Mar. 10, 1925	1.501
Dec. 17, 1924	1.495	Apr. 8, 1925	1.513
Jan. 7, 1925	1.494	May 20, 1925	1.488
Feb. 6, 1925	1.529	June 5, 1926	1.425

Basing conclusions on these collections alone, it was natural to conclude that temperature has a very decided effect on the size of cod eggs, causing them to average larger during the colder periods and decrease in size as the water becomes warmer. Thus, in Massachusetts Bay eggs averaged smallest in December and May and largest in February. In the region of the Labrador current the largest average was found at the northernmost station and the smallest at the more southerly ones, where the summer warming of the water had become noticeable.

In order to determine whether the variations are explainable on the basis of temperature alone, experiments were carried on at Gloucester and on the Boars Head fishing grounds in April, 1926. Eggs and sperm from two fish (*Gadus callarias*) were fertilized in two jars of water, one maintained at 0° C. and the other at 8° C. The water in both jars had been taken from the surface at one spot on the fishing grounds. In general, the results appear significant, 50 eggs fertilized at 0° C. averaging 1.447 millimeters (1.45, 1.44, 1.45, 1.44, and 1.45 millimeters averages in groups of 10) and 50 at 8° C. averaging 1.4106 millimeters (1.41, 1.39, 1.41, 1.43, and 1.41 millimeters). The unfertilized eggs remaining at the bottom of the jars showed the same relationship to temperature, but in each case the average size was somewhat greater than in the developing eggs.

Ehrenbaum found that in the North Sea cod eggs averaged 1.46 millimeters in January and 1.30 millimeters in April. Fifty cod eggs from the Gloucester hatchery averaged 1.497 millimeters on March 25, 1925; of these, 4 per cent were 1.35 millimeters; 14 per cent, 1.40 millimeters; 16 per cent, 1.45 millimeters; 38 per cent, 1.50 millimeters; 10 per cent, 1.55 millimeters; 14 per cent, 1.60 millimeters; and 4 per cent, 1.65 millimeters. Welsh found that artificially fertilized eggs in the Gulf of Maine averaged 1.46 millimeters, but no date is given.

Where water temperatures are more or less even over large areas, cod eggs at two or more spawning centers may average the same in size. In such cases it would not be possible, of course, to make distinctions on the grounds themselves, and any estimates would have to be based on the abundance of eggs traversing a known course from one spawning center to another.

TABLE 15.—*Hydrographic data, Massachusetts Bay and Ipswich Bay. Tables of temperature and salinity*

Cruise, date, and station	Depth, meters	Temperature, ° C.
First cruise, 1924		
Dec. 3:		
Sta. 8	0	6.85
	23	6.80
Sta. 9	0	6.93
	33	6.40
Sta. 10	0	6.74
	33	6.80
Sta. 11	0	6.84
	35	6.85
Sta. 12	0	6.51
	27	6.40
Sta. 13	0	5.83
	20	5.80
Sta. 14	0	5.13
	18	4.90
Sta. 15	0	4.82
	20	4.80
Sta. 16	0	5.62
	24	5.80
Sta. 17	0	6.83
	38	6.90
Second cruise, 1924		
Dec. 11:		
Sta. 2	0	6.75
	33	6.79
	66	6.85
Sta. 3	0	6.50
	13	7.50
	26	6.55
Sta. 4	0	6.70
	31	6.42
	62	6.90
Sta. 5	0	5.30
	20	5.43
	40	5.30
Dec. 9:		
Sta. 7	0	6.30
	6	6.32
	12	6.30
Sta. 9	0	6.30
	14	6.73
	28	6.10
Sta. 10	0	6.90
	18	6.93
	36	7.10
Sta. 11	0	6.80
	18	6.82
	36	6.70
Sta. 12	0	6.90
	14	6.42
	28	--------
Sta. 13	0	5.85
	17	5.73
	34	5.50
Sta. 14	0	5.90
	13	5.87
	26	5.80
Sta. 15	0	4.95
	12	4.93
	24	4.90
Sta. 16	0	5.65
	12	5.62
	24	6.10
Sta. 17	0	6.50
	18	6.42
	36	6.50
Third cruise, 1924		
Dec. 16:		
Sta. 2	0	5.95
	28	5.97
	56	5.95
Sta. 5	0	4.60
	21	4.93
	42	4.25
Sta. 6	0	5.20
	13	5.34
	26	4.70
Sta. 7	0	4.25
	7	4.43
	14	4.34
Sta. 9	0	4.90
	17	4.93
	34	4.40
Dec. 17:		
Sta. 10	0	5.40
	18	5.47
	36	5.90
Sta. 11	0	5.40
	18	5.93
	36	6.10
Sta. 12	0	5.60
	13	5.62
	26	6.05
Sta. 13	0	5.80
	12	5.83
	24	5.05
Sta. 14	0	4.60
	11	4.51
	22	4.20
Sta. 15	0	4.25
	10	4.25
	20	4.25
Sta. 16	0	3.80
	13	4.50
	26	4.80
Dec. 16:		
Sta. 17	0	5.15
	16	5.34
	32	5.20
Sta. 18	0	5.40
	30	5.49
	60	5.45
Fourth cruise, 1924		
Dec. 22:		
Sta. 2	0	4.90
	32	4.62
	64	4.90
Sta. 5	0	4.50
	20	4.95
	41	4.50
Sta. 6	0	4.90
	14	4.55
	28	4.80
Sta. 9	0	4.80
	17	4.83
	34	4.80
Sta. 10	0	4.60
	19	4.63
	37	4.80
Dec. 23:		
Sta. 11	0	4.50
	18	4.63
	35	4.60
Sta. 12	0	--------
	16	4.63
	31	3.50
Fourth cruise, 1924—Continued		
Dec. 23:		
Sta. 13	0	2.50
	13	4.54
	25	4.50
Sta. 14	0	4.50
	8	2.56
	16	3.90
Sta. 15	0	3.50
	12	4.54
	24	3.00
Sta. 16	0	4.50
	13	4.54
	25	4.50
Dec. 22:		
Sta. 17	0	4.90
	19	4.53
	35	4.50
Sta. 18	0	4.50
	32	5.03
	64	4.50
Fifth cruise, 1925		
Jan. 6:		
Sta. 2	0	4.05
	32	4.07
	64	4.15
Sta. 4	0	3.65
	29	3.87
	58	4.05
Sta. 5	0	2.80
	19	2.85
	39	2.80
Sta. 6	0	2.45
	12	2.48
	24	2.70
Sta. 7	0	0.36
	6	0.37
	13	0.25
Jan. 7:		
Sta. 9	0	2.15
	16	2.20
	32	2.15
Sta. 10	0	2.25
	19	2.47
	37	2.15
Sta. 11	0	2.00
	18	2.00
	35	1.15
Sta. 12	0	2.15
	13	1.67
	26	1.55
Sta. 13	0	2.00
	13	1.90
	25	1.90
Sta. 14	0	2.15
	13	2.23
	25	2.05
Sta. 15	0	2.05
	10	2.53
	20	2.95
Sta. 16	0	2.70
	10	2.70
	20	2.70
Jan. 6:		
Sta. 18	0	3.50
	32	3.57
	63	4.35
Sta. 19	0	3.95
	29	3.97
	58	4.10

TABLE 15.—*Hydrographic data, Massachusetts Bay and Ipswich Bay. Tables of temperature and salinity*—Continued

Cruise, date, and station	Depth, meters	Temperature, ° C.	Salinity, per mille
Sixth cruise, 1925			
Feb. 6:			
Sta. 2	0	2.00	32.87
	32	1.91	32.90
	63	3.10	32.83
Sta. 4	0	.60	32.51
	30	.60	32.61
	60	1.00	32.74
Sta. 5	0	.60	32.43
	20	−.14	--------
	39	.10	--------
Sta. 6	0	.20	32.23
	8	.81	32.29
	16	.00	32.57
Sta. 6A	0	−.60	32.62
	17	−1.55	32.45
	34	−.40	32.74
Sta. 7	0	−.70	32.35
	6	−.41	32.47
	11	−.60	32.66
Sta. 9	0	1.90	32.70
	15	.59	32.78
	29	.70	33.19
Feb. 7:			
Sta. 10	0	1.00	32.77
	18	.87	32.62
	35	.80	32.79
Sta. 11A	0	1.10	32.67
	18	1.01	32.97
	36	1.20	32.92
Sta. 13A	0	1.20	32.81
	16	1.10	32.94
	32	1.10	33.04
Sta. 14	0	−.10	32.72
	11	−.20	32.98
	22	.20	32.78
Sta. 15	0	.00	32.67
	12	−.50	32.63
	23	2.00	32.91
Sta. 16	0	.00	32.54
	12	−.10	32.92
	24	.50	32.95
Feb. 6:			
Sta. 18A	0	2.00	33.01
	34	1.85	33.08
	68	2.00	32.90
Sta. 19	0	2.60	33.13
	35	2.06	33.26
	70	2.60	33.18
Seventh cruise, 1925			
Feb. 24:			
Sta. 2	0	2.10	32.75
	32	1.83	32.71
	64	1.90	33.07
Sta. 5	0	2.30	32.29
	22	1.88	32.61
	43	2.34	32.99
Sta. 7	0	1.60	32.25
	6	1.48	32.35
	12	1.39	32.34
Feb. 28:			
Sta. 10	0	1.10	--------
	19	1.43	--------
	36	1.40	--------
Sta. 13A	0	1.21	--------
	15	1.13	--------
	30	1.21	--------
Sta. 15	0	1.21	--------
	12	1.21	--------
	22	1.30	--------
Feb. 24:			
Sta. 18A	0	2.00	33.14
	35	1.70	32.51
	70	2.20	33.10

Cruise, date, and station	Depth, meters	Temperature, ° C.	Salinity, per mille
Eighth cruise, 1925			
Mar. 10:			
Sta. 2	0	2.40	32.94
	33	2.14	32.98
	65	2.05	33.12
Sta. 10	0	2.00	32.66
	17	1.63	32.61
	33	2.17	32.52
Sta. 13A	0	1.70	32.61
	13	1.64	--------
	25	1.45	32.36
Sta. 15	0	2.00	32.43
	11	1.67	32.47
	21	1.95	32.58
Sta. 18A	0	1.90	32.90
	38	1.88	32.91
	76	1.85	33.01
Ninth cruise, 1925			
Mar. 12:			
Sta. 20	0	3.50	31.47
	32	2.60	32.94
	64	2.70	33.11
Sta. 21	0	3.60	30.71
	21	2.81	33.08
	41	2.45	33.19
Sta. 22	0	3.80	32.41?
	15	2.46	32.86
	30	2.44	32.94
Sta. 25	0	3.60	31.47
	25	2.40	32.47
	49	2.44	33.02
Sta. 26	0	3.70	31.03
	17	2.36	32.81
	33	2.40	32.94
Sta. 28	0	3.10	32.10
	22	2.60	32.70
	43	2.60	33.21
Tenth cruise, 1925			
Mar. 25:			
Sta. 21	0	3.80	--------
	32	2.71	--------
	64	2.82	--------
Sta. 22	0	3.60	--------
	20	2.72	--------
	39	2.48	--------
Sta. 23	0	3.70	--------
	40	--------	--------
	79	2.89	--------
Sta. 24	0	3.60	--------
	16	2.73	--------
	33	2.57	--------
Sta. 25	0	3.80	--------
	38	2.63	--------
	75	2.90	--------
Sta. 26	0	3.40	--------
	12	3.27	--------
	24	2.64	--------
Sta. 27	0	3.35	--------
	38	2.63	--------
	76	2.85	--------
Sta. 28	0	3.60	--------
	18	2.83	--------
	37	2.59	--------
Eleventh cruise, 1925			
Apr. 7:			
Sta. 3	0	4.10	--------
	30	4.08	--------
	60	3.40	--------
Sta. 4	0	4.40	--------
	30	4.20	--------
	60	3.58	--------

Cruise, date, and station	Depth, meters	Temperature, ° C.	Salinity, per mille
Eleventh cruise, 1925—Contd.			
Apr. 8:			
Sta. 6	0	4.90	--------
	13	4.86	--------
	26	5.14	--------
Sta. 6A	0	4.75	31.86
	22	4.40	--------
	45	2.86	32.50
Sta. 7	0	5.40	--------
	6	5.25	--------
	12	5.26	--------
Sta. 10	0	4.10	31.18
	20	4.59	--------
	40	2.46	32.26
Sta. 13A	0	5.40	--------
	12	4.63	--------
	24	3.81	--------
Sta. 14	0	5.10	--------
	10	5.22	--------
	20	4.65	--------
Sta. 16	0	5.05	--------
	15	4.93	--------
	30	3.52	--------
Apr. 7:			
Sta 21	0	4.90	28.75
	20	2.62	--------
	39	2.61	31.80
Sta. 23	0	4.60	--------
	37	2.43	--------
	75	2.48	--------
Sta. 25	0	4.75	--------
	33	2.87	--------
	65	2.78	--------
Sta. 28	0	4.20	29.02
	26	2.57	--------
	51	2.61	33.15
Sta. 29	0	4.55	--------
	20	2.83	--------
	39	2.81	--------
Sta. 30	0	4.30	--------
	42	3.13	--------
	84	3.11	--------
Sta. 31	0	4.05	32.02
	57	2.86	--------
	112	2.90	32.59
Sta. 32	0	4.40	--------
	30	3.33	--------
	60	2.72	--------
Sta. 33	0	4.60	31.91
	40	3.69	--------
	80	2.91	33.18
Sta. 34	0	4.40	32.01
	22	2.94	--------
	44	3.12	32.68
Twelfth cruise, 1925			
Apr. 22:			
Sta. 3	0	5.50	31.71
	17	5.49	31.62
	33	3.79	32.50
Sta. 4	0	6.00	31.87
	27	5.20	31.76
	55	4.18	32.32
Sta. 6	0	6.80	32.01
	15	4.63	31.67
	30	3.79	32.21
Sta. 6A	0	6.60	31.75
	17	5.77	31.43
	35	4.98	31.71
Apr. 23:			
Sta. 7	0	6.30	31.55
	6	--------	--------
	12	6.48	31.42
Sta. 10	0	5.60	31.60
	22	5.54	31.44
	44	4.87	31.66

TABLE 15.—*Hydrographic data, Massachusetts Bay and Ipswich Bay. Tables of temperature and salinity*—Continued

Cruise, date, and station	Depth, meters	Temperature, ° C.	Salinity, per mille
Twelfth cruise, 1925—Contd.			
Apr. 23.			
Sta. 14	0	5.30	31.90
	10	5.10	31.72
	20	4.60	31.69
Sta. 16	0	5.70	31.55
	12	5.10	31.62
	24	4.58	31.66
Sta. 17	0	5.60	31.63
	17	5.13	31.71
	35	4.60	31.56
Sta. 18A	0	6.40	31.86
	35	4.00	32.00
	70	2.88	32.48
Apr. 22:			
Sta. 29	0	4.20	31.13
	22	4.23	31.04
	44	3.56	32.00
Sta. 30	0	4.00	31.79
	40	3.42	32.38
	80	2.92	32.82
Sta. 31	0	4.40	31.30
	42	2.63	32.47
	84	2.70	32.81
Sta. 32	0	4.30	31.47
	25	4.11	31.66
	50	3.09	32.41
Sta. 33	0	4.40	32.00
	32	4.18	32.57
	64	3.06	32.65
Sta. 34	0	4.50	31.86
	25	4.02	32.01
	50	3.48	32.91
Sta. 35	0	4.40	31.26
	22	4.23	31.66
	44	3.66	31.86
Apr. 21:			
Sta. 36	0	5.20	31.53
	22	4.83	31.72
	44	3.95	31.65
Sta. 37	0	4.20	31.59
	19	4.83	31.75
	38	4.60	32.00
Sta. 38	0	6.00	31.47
	13	4.57	31.40
	26	4.75	32.09
Thirteenth cruise, 1925			
May 21:			
Sta. 3	0	8.50	31.47
	15	8.14	31.36
	30	5.15	31.59
Sta. 4	0	9.80	31.58
	30	3.83	32.36
	60	3.20	32.35
May 20:			
Sta. 6	0	10.20	31.63
	15	9.95	31.65
	30	9.88	31.78
Sta. 6A	0	10.20	31.73
	17	--------	31.44
	34	4.62	31.89
Sta. 7	0	11.00	31.82
	6	10.96	31.69
	12	10.92	31.64
Sta. 10	0	9.00	31.76

Cruise, date, and station	Depth, meters	Temperature, ° C.	Salinity, per mille
Thirteenth cruise, 1925—Continued			
May 20:			
Sta. 10	17	5.14	31.56
	34	3.99	31.92
Sta. 14	0	8.80	31.85
	10	8.84	--------
	20	4.69	31.87
Sta. 16	0	8.40	31.39
	13	8.64?	31.55
	26	8.52	31.39
Sta. 17	0	8.70	31.60
	16	5.00	31.96
	32	3.68	32.20
Sta. 18A	0	8.15	31.50
	40	3.71	32.29
	80	3.08	32.38
May 21:			
Sta. 29	0	7.10	31.44
	32	3.38	32.61
	64	3.21	32.42
Sta. 30	0	9.40	31.11
	25	3.51	32.21
	50	3.30	32.21
Sta. 31	0	9.40	31.27
	81	3.12	--------
	162	3.10	32.59
Sta. 32	0	9.20	31.66
	35	3.40	32.41
	70	3.09	32.56
Sta. 33	0	8.30	31.74
	25	5.04	32.26
	50	3.28	32.52
Sta. 34	0	9.00	31.59
	28	4.30	32.29
	56	3.31	32.36
Sta. 35	0	8.00	31.47
	22	3.78	32.05
	44	3.31	32.74
May 22:			
Sta. 36	0	6.95	31.87
	23	3.99	32.51
	46	3.72	32.47
Sta. 37	0	8.72	31.71
	20	4.39	32.99
	39	3.69	31.89
Sta. 38	0	9.25	31.35
	15	4.33	32.02
	30	3.86	--------
Fourteenth cruise, 1925			
June 17:			
Sta. 3	0	12.13	32.38
	10	12.05	32.38
	20	9.23	32.52
	30	5.06	33.17
Sta. 4	0	14.79	32.30
	10	14.35	32.30
	20	7.47	32.81
	40	3.75	33.23
	60	3.74	33.24
June 16:			
Sta. 6A	0	15.01	31.80
	10	14.91	32.01
	20	8.47	32.38
	34	4.66	32.45

Cruise, date, and station	Depth, meters	Temperature, ° C.	Salinity, per mille
Fourteenth cruise, 1925—Continued			
June 16:			
Sta. 7	0	15.23	32.23
	10	15.20	32.38
Sta. 10	0	14.43	32.16
	10	12.83	32.23
	20	5.98	32.81
	38	5.69	32.95
Sta. 14	0	15.21	32.09
	10	10.66	32.38
	22	7.56	32.66
Sta. 16	0	15.17	32.09
	10	15.14	32.09
	26	6.76	32.66
Sta. 17	0	15.00	32.23
	10	14.32	32.16
	20	7.27	32.66
	37	4.65	32.95
Sta. 18A	0	15.22	32.33
	10	13.88	32.16
	20	6.11	32.95
	40	3.55	33.39
	79	3.23	33.24
June 17:			
Sta. 29	0	12.91	32.09
	10	12.24	32.09
	20	11.87	32.09
	48	5.19	32.88
Sta. 30	0	13.33	32.38
	10	12.08	32.66
	20	6.39	32.95
	40	4.23	33.24
	75	4.04	33.24
Sta. 31	0	12.94	32.66
	10	9.11	32.74
	20	5.45	33.10
	40	4.00	33.17
	94	3.47	33.24
Sta. 32	0	12.43	32.52
	10	9.62	32.59
	20	4.56	33.39
	50	3.97	33.17
Sta. 33	0	12.94	32.59
	10	11.81	32.45
	20	5.20	33.17
	50	4.09	33.17
Sta. 34	0	12.11	32.59
	10	11.06	32.38
	20	5.56	33.03
	56	3.91	33.10
Sta. 35	0	13.16	32.09
	10	12.72	32.16
	20	12.03	32.30
	40	6.14	32.66
Sta. 36	0	13.53	32.23
	10	12.15	32.38
	20	12.06	32.66
	44	4.61	32.88
Sta. 37	0	12.16	32.38
	10	10.24	32.45
	20	9.08	32.66
	42	5.30	32.88
Sta. 38	0	12.76	32.16
	10	9.75	32.52
	20	8.93	32.52
	28	5.92	32.81

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COREGONID FISHES OF THE GREAT LAKES

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CONTENTS

GENERAL REMARKS

THE COREGONID FISHES

The family Salmonidæ, as formerly constituted, contains less than 100 species, which are distributed in the temperate and arctic regions. In the systematic arrangement formerly followed by ichthyologists it was divided into two subfamilies—the Coregoninæ and the Salmoninæ. Cope (1872) thought that the differences between the two types of fishes concerned were sufficiently marked to place them in separate families. Accordingly, he proposed the family Coregonidæ for those fish of the group with united parietals and retained Salmonidæ for those with parietals separated by the supraoccipital. Gill (1895) believed that Cope was wrong in his observation that the parietals were united in Coregonus, reduced Coregonidæ to subfamily rank, and combined it with Salmoninæ under the Salmonidæ. Regan (1914) retained these subfamilies but not the characters on which Gill based them. Regan's Coregoninæ are Salmonidæ with "parietals meeting in the middle line;

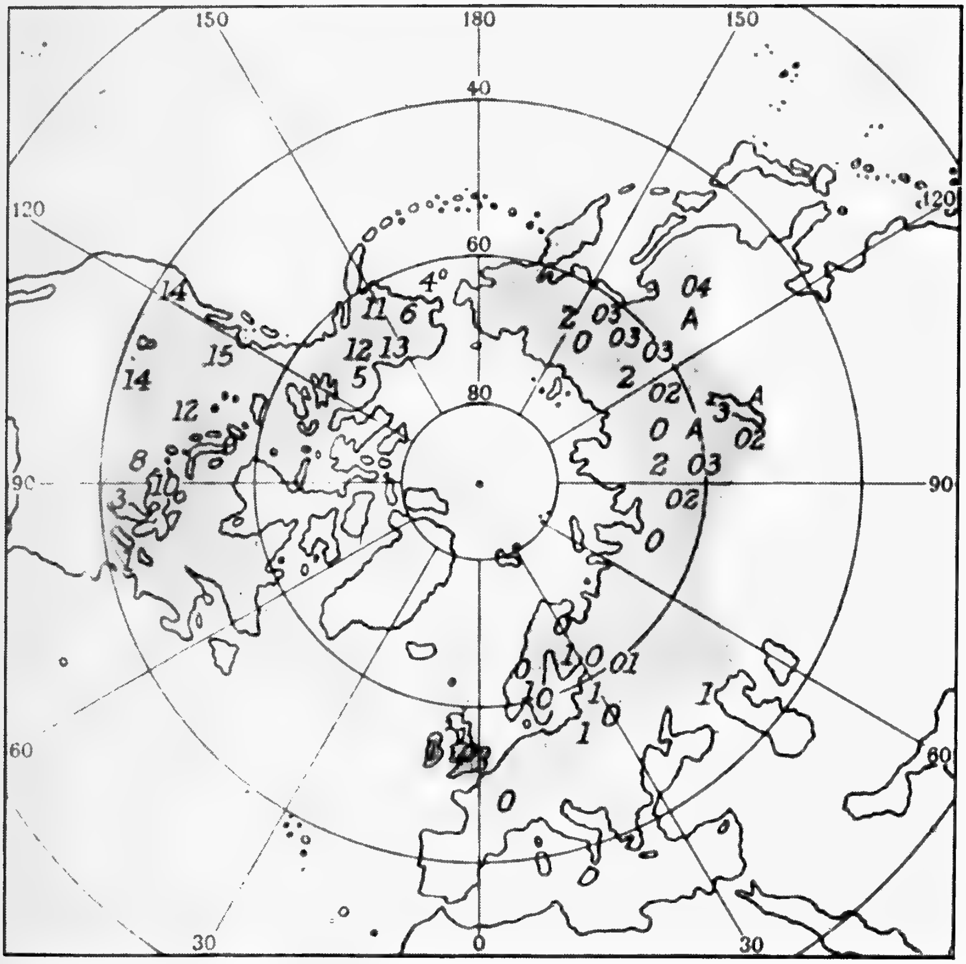


Fig. 1.—Map of the boreal regions, showing approximately the known distribution of the coregonids. Modified after Meek

teeth on vomer and tongue, when present, in several series; scales larger, 13 or less in a transverse series from the origin of the dorsal fin to the lateral line." Regan recognized four genera—Stenodus, Coregonus, Phylogephyra, and Thymallus. Coregonus is distinguished from the others chiefly by having no teeth or vestigial ones. In agreement with Cope recent American writers have accepted the family Coregonidæ, and I follow current American practice in this paper.

The genus Coregonus, as recognized by Regan and most other European ichthyologists, includes all the known species of whitefish and lake herring, but certain American ichthyologists have recognized several minor groups of species and have given them generic or subgeneric names. Thus, the lake herrings are placed by Jordan and Evermann (1911) in the genus Leucichthys under three subgenera, Thrissomimus, Cisco, and Allosomus, while the whitefishes are placed in the genus Coregonus under the subgenera Coregonus and Prosopium. For reasons to be given later, I do not find their arrangement satisfactory. I hold the three groups Leucichthys, Coregonus, and Prosopium as distinct genera and disregard the subgenera of Leucichthys.

The genus Coregonus of the Europeans, which is approximately the family Coregonidæ of Americans, has an almost completely circumpolar distribution. (See fig. 1.) The various species occur in rivers, lakes, or in the ocean. Certain Siberian species spend most of their life in the Arctic Ocean but ascend rivers periodically; while others, notably the Scandinavian species *albula* and *lavaretus* and the American *quadrilaterale*, are supposed to occur in lakes, rivers, and in the sea. Most of the recognized species, however, are confined to inland lakes.

STATEMENT OF THE PROBLEM

Wherever they occur, the coregonids, like the salmonids, are important food fishes; but probably nowhere else do they attain so much importance in the fisheries as in the region of the Great Lakes. In view of the great importance of these fisheries it is desirable, from a purely economic point of view, to determine what forms are found in the various lakes of the region and to obtain full knowledge of the natural history of these forms and of the conditions under which they live. Without such knowledge any legislative or fish-cultural steps designed to conserve the fisheries concerned must be unintelligent in character and their success must be a matter of chance. The present investigation had as its object the determination of the forms of coregonid fishes that occur in these lakes and the collection of data on their natural history. In addition to its economic significance, the problem is one of scientific interest. It concerns not merely the ecology of the Great Lakes species but it involves also the ultimate consideration of their origin and evolution and of their relationships with one another and with the coregonids of Asia and Europe, as well as with those of other parts of America.

SOURCE OF MATERIAL AND DATA

THE GREAT LAKES

This investigation of the systematic relationships and the natural history of the coregonids was begun on Lake Huron for several reasons. Inasmuch as this lake, together with the North Channel and Georgian Bay, presents a maximum differentia-

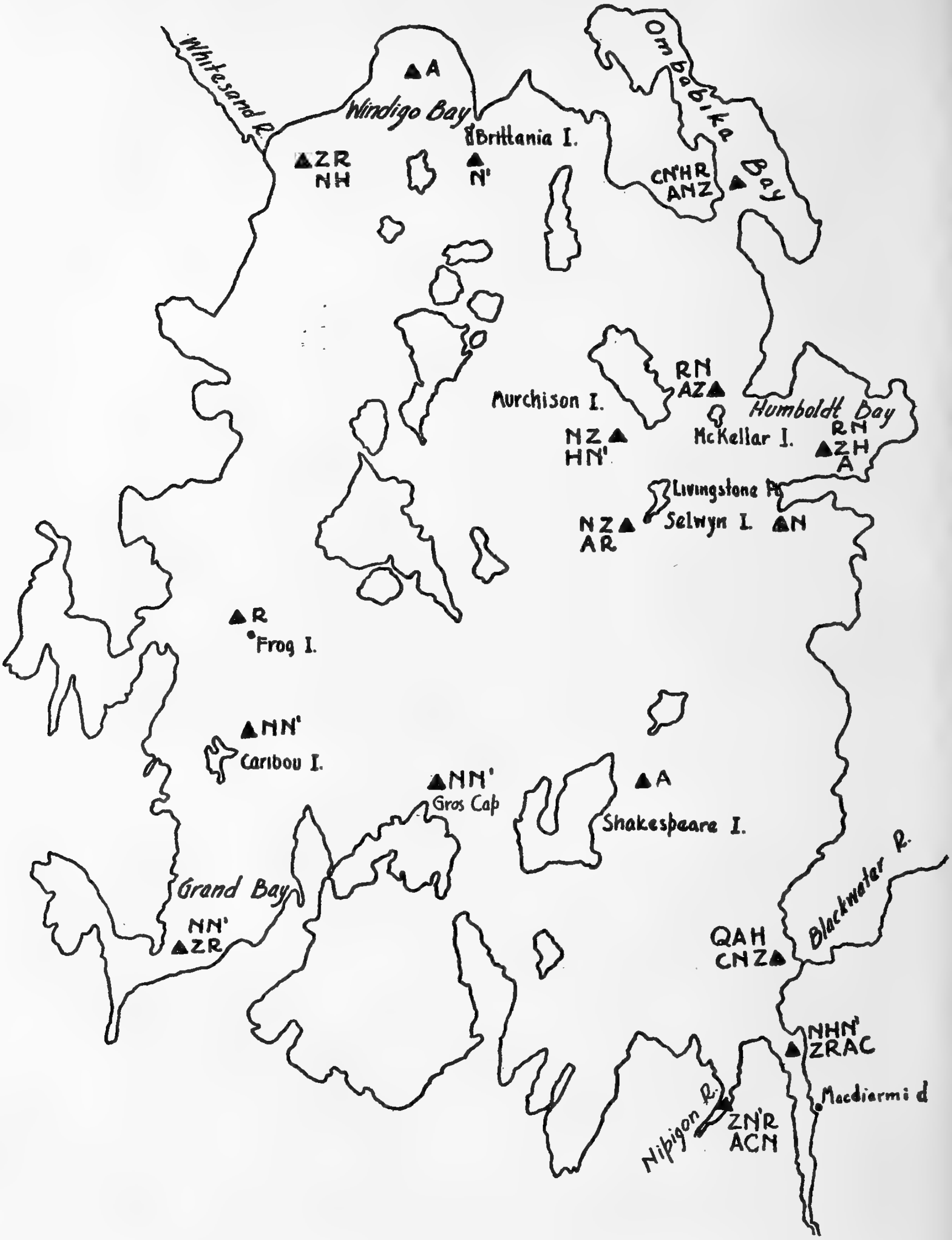


FIG. 2.—Lake Nipigon, showing the location of the distribution records of the various coregonids from Tables 26, 34, 46, 62, 75, 79, and 90. The letters beside the triangles are the first letters of the various specific names, except that for *Leucichthys nipigon* the letter N′ has been used and for *Leucichthys alpenæ* the letter A′. The letters N and A appearing elsewhere in the figure represent *L. nigripinnis* and *L. artedi.*

tion of aquatic habitats, and as these are, for the most part, of considerable extent, it was to be expected that the maximum number of Great Lakes forms would be found here. In addition to this, there are many fishing ports on the lake, and out of most of these various kinds of apparatus are in use, in shallow water as well as in the deeper waters, so that a considerable variety of species is taken at such ports.

The investigations were extended subsequently to the other lakes. In Lakes Michigan and Erie the commercial fishing operations are at least as extensive and varied as in Lake Huron, but in Lakes Superior, Nipigon, and Ontario the smaller species of fishes, including Leucichthys, are sought for but little by commercial fishermen, so that on the latter lakes I was compelled to make use of special apparatus. The lakes themselves differ considerably in their physical characteristics and consequently are not equal in productivity.

Lake Nipigon

Lake Nipigon, in Canadian territory, is the smallest and most northerly, as well as one of the shallowest, of the series of lakes considered in this paper. It is about 65 miles long by 40 miles wide, but its area is much interrupted by numerous islands and shallow bays, so that the total water surface is only about 1,530 square miles. Throughout most of its area the depth is less than 30 fathoms, though small areas are known with a depth of about 60 fathoms. It is connected with Lake Superior through the Nipigon River, but a fall at the river's source probably prevents the interchange of members of the fish fauna. The Canadian authorities opened the lake to commercial fishing in 1916 and have attempted to regulate the number of fishing boats and the maximum output. The annual production, which so far has been principally whitefish and trout, has averaged around 1,500,000 pounds, of which the true whitefish has constituted more than two-thirds.

Lake Superior

Lake Superior lies at the head of the Great Lakes and is the largest, deepest, and coldest of the chain. Its northern and eastern waters are controlled by the Province of Ontario, those on the south by the States of Michigan and Wisconsin, and those on the west by Minnesota. It receives the waters of Lake Nipigon to the northward and drains through St. Marys River into the North Channel. The lake is broadly crescentic in shape, with a length of about 355 miles and a width on the western half of about 70 miles and on the eastern half of 90 to 110 miles. Its area is about 32,000 square miles. The main body of the lake is more than 100 fathoms in depth, and a sounding of 196 fathoms has been recorded. The shore on the outer curve of the crescent is precipitous, and at many points a 100-fathom depth can be reached within 2 miles of land. The bottom slopes more gradually from the southern shore, and the 50-fathom contour is on the average about 5 or 6 miles out. There are several bays and a number of large islands in the lake, in and around which conditions are more tempered than in the lake itself. These areas, however, are relatively insignificant, and the only important stretches of shallow water lie in the Apostle Islands region, Whitefish Bay, and in the bay region on the north shore. The shores are rocky for the most part, except on the south, where there are broad stretches of sand, gravel, and clay. Most of the bottom in the deeper parts is clay.

The principal species of commercial fish are the whitefish, trout, and herring. The annual production has averaged about 15,000,000 pounds, of which the coregonids have comprised the bulk.

Lake Michigan

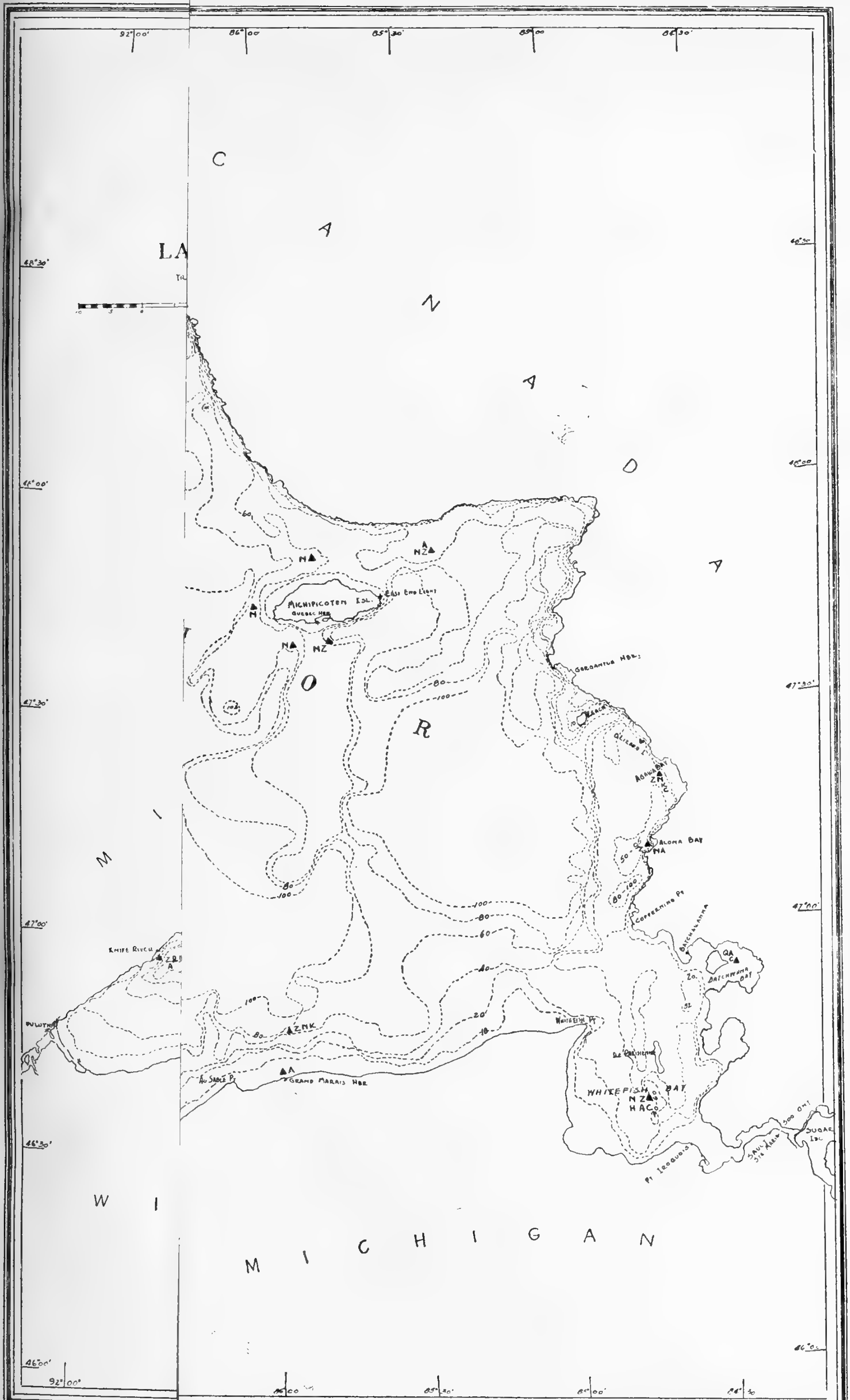
Lake Michigan is the only one of the Great Lakes that lies wholly within American jurisdiction. On the north and east its waters are controlled by the State of Michigan, on the west by Wisconsin and Illinois, and at the extreme south by Indiana. The lake is about 325 miles long, with an average width of 65 miles and an area of about 22,000 square miles. In the lake bottom are two basins—one at each end—separated in the center by an uneven stretch about 60 miles in length, which bears several well-defined though yet uncharted reefs. From the south the bottom slopes very gradually (at the rate of 1 or 2 fathoms to a mile) into a basin with a maximum recorded depth of 97 fathoms. In this depression a somewhat circular area, about 40 miles in diameter, is inclosed by the 60-fathom contour. The rise to the elevation in the center is rather abrupt and begins about 100 miles from the southern shore. The most extensive depression extends for about 100 miles in the northern half of the lake and is overlaid by 90 to 144 fathoms of water. The 90-fathom contour roughly outlines a triangle with the apex pointing north. For about 50 miles the figure has an average width of 30 miles and then tapers rapidly. So far as is known this area is not productive. The rest of the northern sector is dotted with islands and reefs with conspicuous depressions between. Green Bay, with an approximate area of 1,700 square miles and a maximum depth of about 20 fathoms, and Grand Traverse Bay, with an area of about 300 square miles and a maximum depth of more than 100 fathoms, are the only extensive bays, and both lie near the north end. The bottom along the shore is largely sand, but there are stretches of clay and, in the north, of rock. The deeper waters overlie clay for the most part.

The principal species are whitefish, chubs, herring, trout, perch, and suckers. The annual production has been about 25,000,000 pounds, of which usually half or more were coregonids.

Lake Huron

Lake Huron is situated in the center of the Great Lakes chain, and its waters lie about equally within the jurisdiction of the Province of Ontario on the east and the State of Michigan on the west. It receives the waters of Lake Superior through St. Marys River and those of Lake Michigan through the Straits of Mackinac. It drains southward through the St. Clair River, Lake St. Clair, and the Detroit River into Lake Erie. Its greatest length, from the head of the St. Clair River to the Straits of Mackinac, is about 250 miles and the greatest width (near the middle) about 100 miles. Excluding Georgian Bay and the North Channel, the lake has an area of approximately 17,500 square miles.

Lake Huron is divided into two approximately equal areas by the Big Reef, which extends continuously from Point Clark, Ontario, to North Point, Mich. North of the reef lie the deepest waters of the lake. Here the 30-fathom contour is rarely more than 10 miles from shore, and a considerable portion of the area lies within the 60-fathom curve. The maximum depth of 125 fathoms known in the lake is found here. The southern portion is shallower. Here depths of 30 fathoms


C
A
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Alona Bay
Coppermine Pt.
Batchawana
Batchawana Bay
Knife River
Duluth
Whitefish Pt.
Au Sable Pt.
Grand Marais Hbr.
Whitefish Bay
Pt. Iroquois
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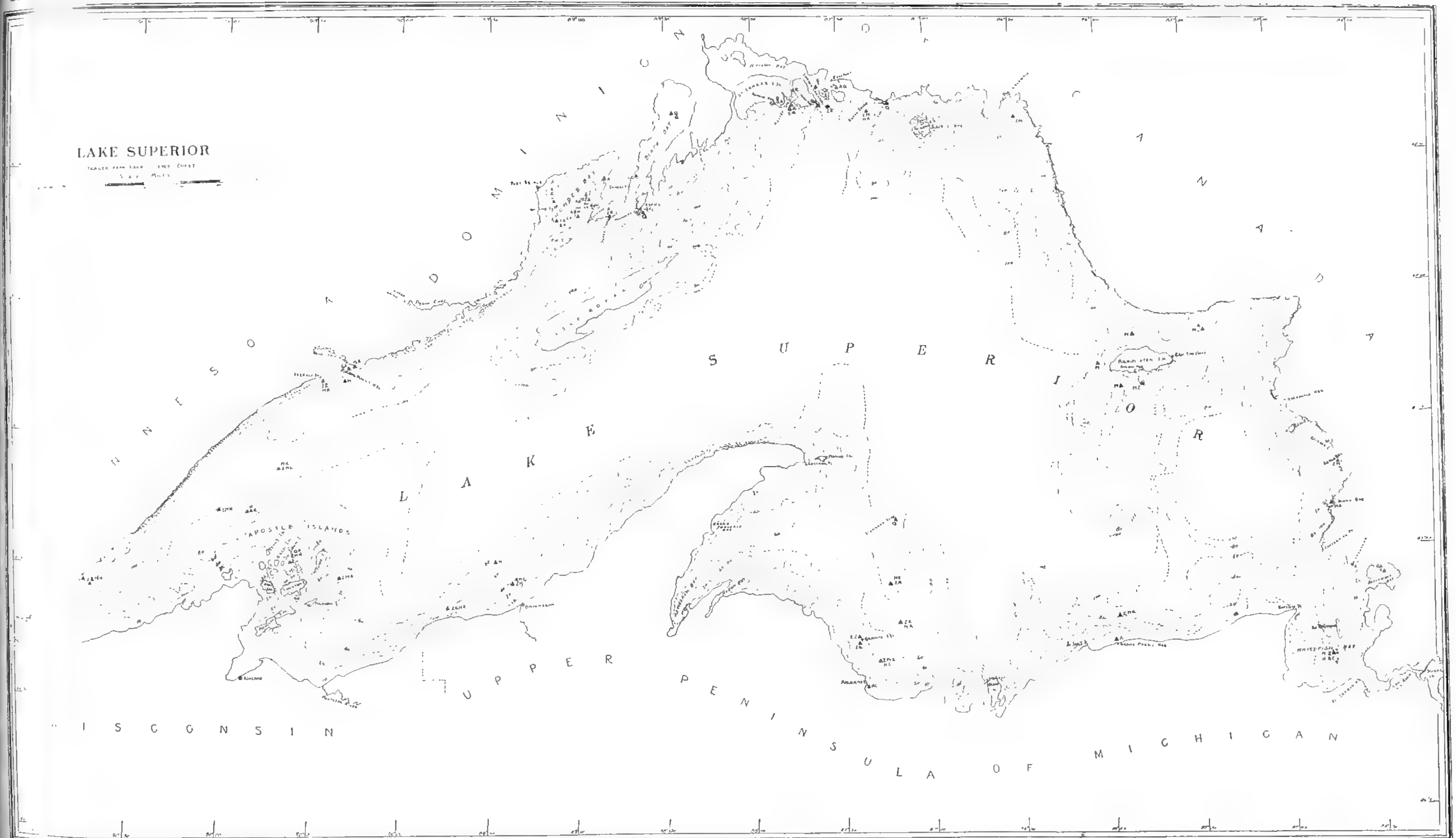

FIG. 3.—Lake Superior, showing the location of the records of occurrence of the coregonids from Tables 24, 36, 44, 52, 60, 73, 87, and 100. (See legend to fig. 2.)


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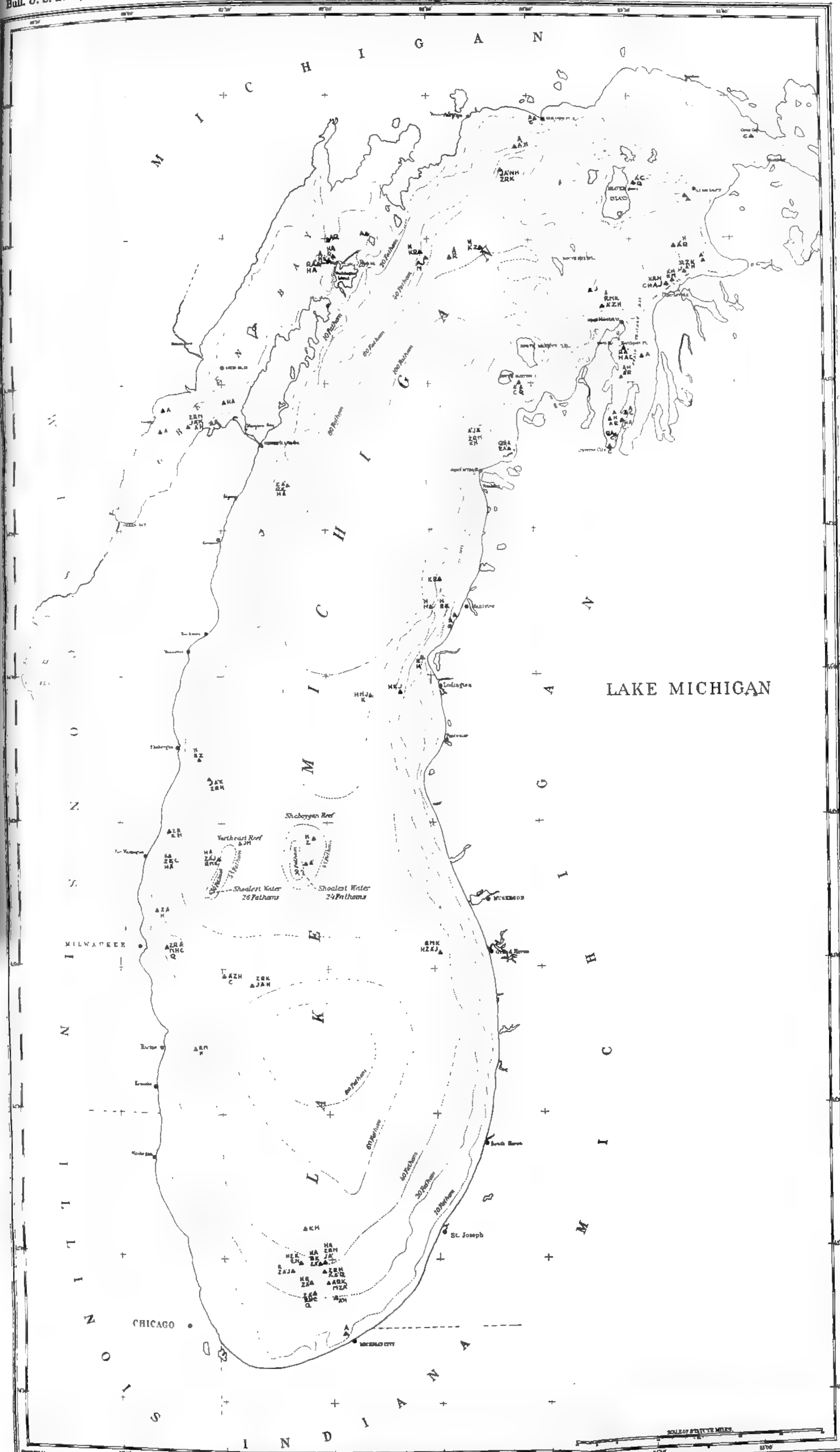
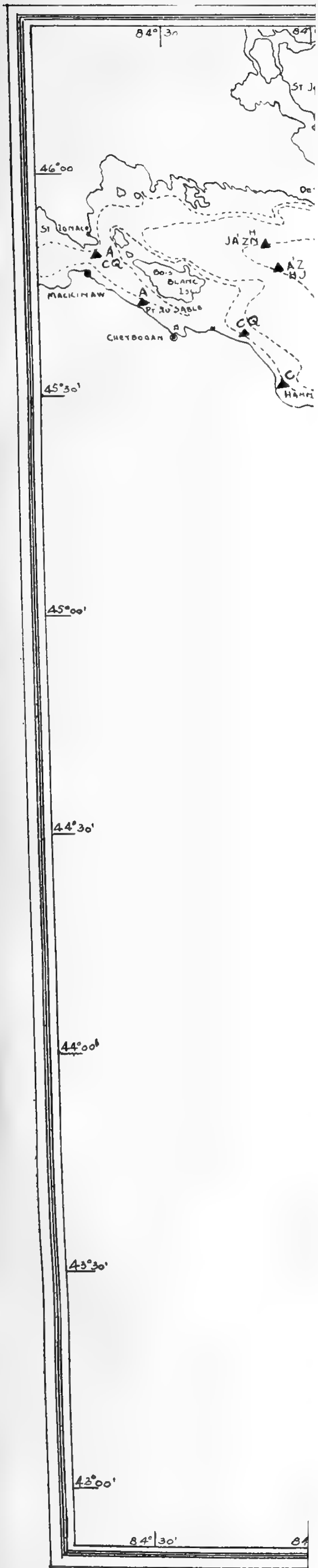


FIG. 4.—Lake Michigan showing the location of the records of the occurrence of the coregonids from Tables 16, 20, 28, 32, 40, 48, 55, 68, 81, and 96. (See legend to fig. 3.)

94995—29. (To face p. 302. No. 2)


84° 30'
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Cheboygan
45°30'
45°00'
44°30'
44°00'
43°30'
43°00'
84° 30'

FIG. 5.

Fig. 5.—Lake Huron, showing the location of the records of occurrence of the coregonids from Tables 18, 22, 30, 42, 50, 58, 70, 84, and 93. (See legend to fig. 2.)

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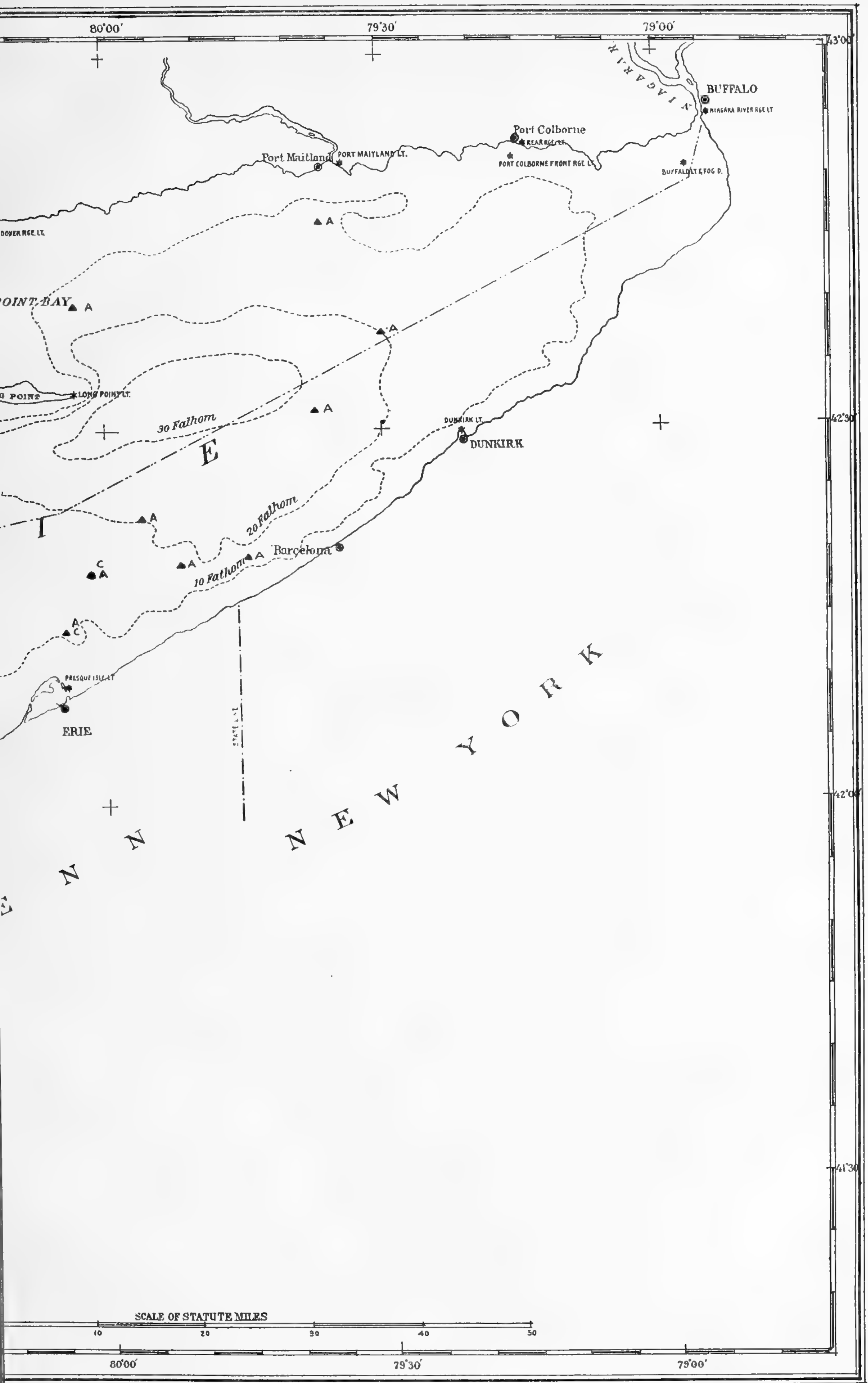

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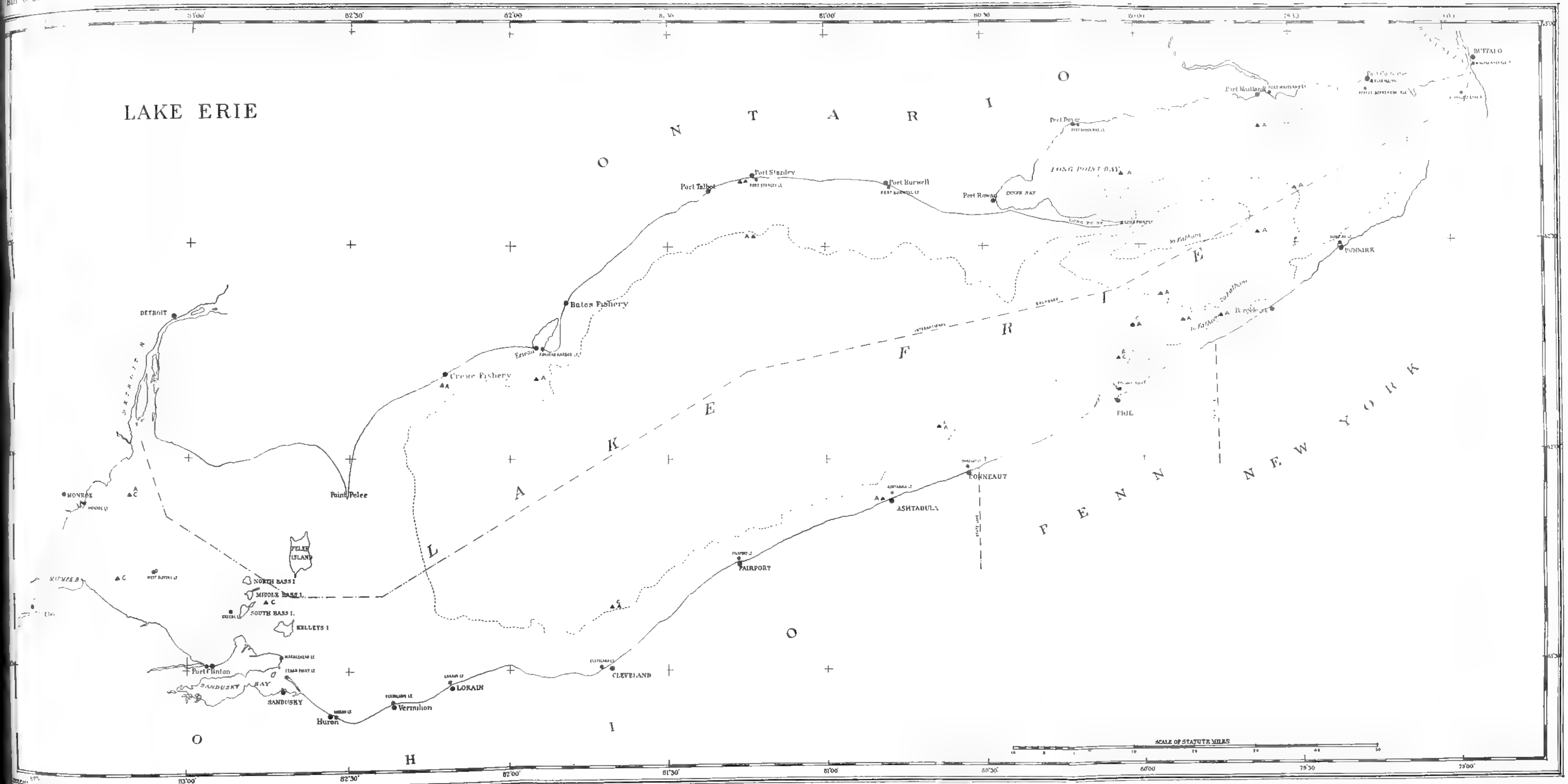

FIG. 6.—Lake Erie, showing the location of the records of occurrence of the coregonids from Tables 66 and 92. (See legend to fig. 2.)

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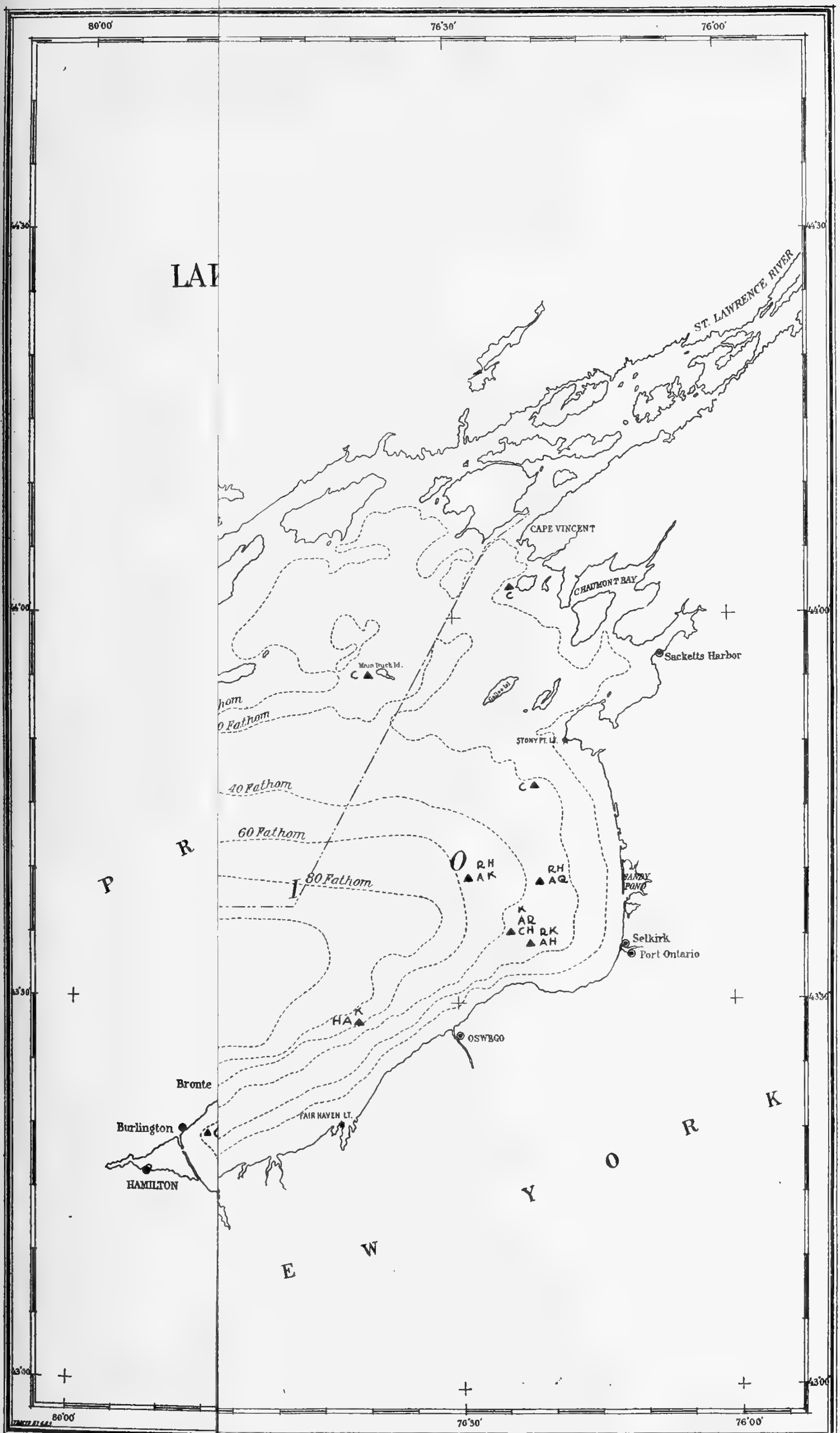

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76°00′
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LAK
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CHAUMONT BAY
Sacketts Harbor
STONY PT. LT.
40 Fathom
60 Fathom
80 Fathom
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Port Ontario
OSWEGO
FAIR HAVEN LT.
Bronte
Burlington
HAMILTON
N E W Y O R K

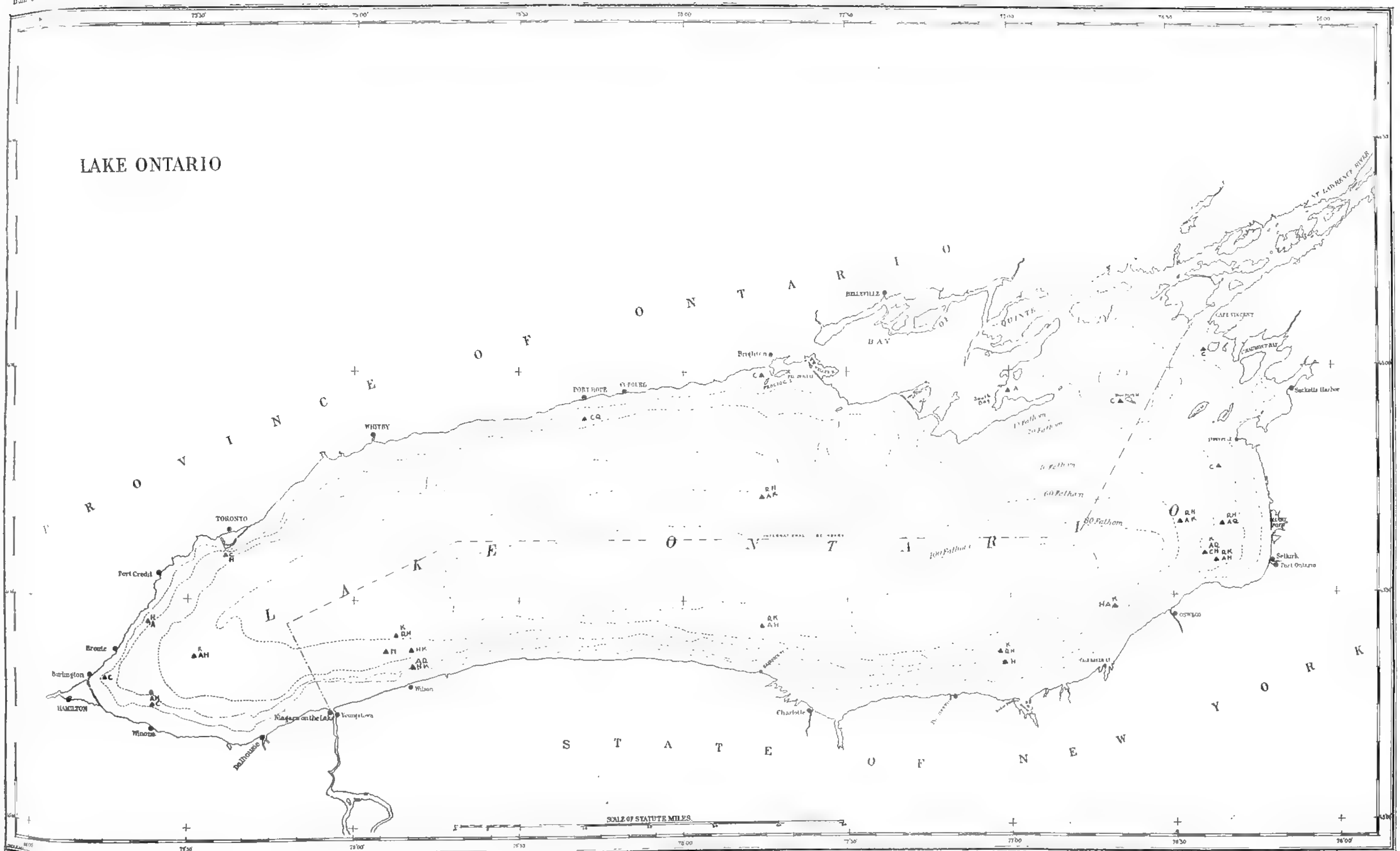

Fig. 7.—Lake Ontario, showing the location of the records of occurrence of the coregonids from Tables 38, 54, 64, 77, and 94. (See legend to fig. 2.)

and less are more extensive, and the maximum depth known is only 54 fathoms. The bottom along shore is variable in character, consisting of rocks, bowlders, gravel, sand, clay, and mud, irregularly distributed. The deeper waters overlie chiefly clay and mud.

Separated from the main body of the lake and wholly within Canadian territory are the divisions known as the North Channel and Georgian Bay. Their water surfaces are approximately 1,500 and 5,000 square miles. From the junction of the North Channel with the St. Marys River to the foot of Georgian Bay at Collingwood is a distance of about 240 miles, while the greatest width of the district, from the mouth of the French River to the junction of Georgian Bay with Lake Huron, is about 60 miles. The North Channel and the northern and eastern shores of the bay are dotted with numerous islands and reefs, and the best fishing grounds are in these sections. The water in the North Channel deepens from north to south, with the maximum depth of 29 fathoms off Manitoulin Island, which forms its southern shore. The average depth is about 20 fathoms. The floor of Georgian Bay is tilted also, but from east to west, so that the deepest waters lie hard off Bruce Peninsula. From the east the slope is gradual, and the 40-fathom contour approximately bisects the bay from north to south. The descent into depths of 60 to 90 fathoms is rapid. The shores for the most part are rocky, but stretches of sand, gravel, and clay are not uncommon. In the deep water the bottom is clay.

Whitefish, herring, chubs, trout, wall-eyed pike, and suckers are the principal species. The annual production has been in Lake Huron, about 15,000,000 pounds, of which coregonids have averaged nearly half. In the North Channel and Georgian Bay the annual production has been around 5,000,000 pounds, of which coregonids constituted about one-third.

Lake Erie

Lake Erie has an area of approximately 10,000 square miles, exceeding in size only Lakes Ontario and Nipigon. Its length is about 250 miles, and the average width is about 45 miles. It is bounded on the north by the Province of Ontario, on the west by the State of Michigan, on the south by Ohio and Pennsylvania, and on the east by New York. Lake Erie receives the waters of the upper Great Lakes through the Detroit River and drains through the Niagara River. The deepest water occurs in the eastern sector, in that part bordered by Pennsylvania, New York, and the portion of the Canadian shore lying eastward of Long Point. The maximum depth recorded is 35 fathoms off Long Point. The stretch for 100 miles between Long Point and Point Pelee is a nearly flat plain covered by no more than 14 fathoms of water. East of Point Pelee is a shelf with numerous islands and reefs, having a maximum depth of 7 fathoms.

Lake Erie offers most favorable conditions for the growth of fish, and in virtually every census, in spite of its small size, it has led all the lakes in quantity of production. On account of its shallowness, warmth, and diversified conditions, many species of fish occur in its waters, and no less than 15 species have been important at one time or another in the commercial catches. In late years the most important species have been herring, whitefish, wall-eyed pike, perch, and saugers. The annual production has ranged probably between 40,000,000 and 75,000,000 pounds, of which the coregonids supplied about half.

94995—29——2

Lake Ontario

Lake Ontario is the easternmost and, excepting Lake Nipigon, the smallest of the Great Lakes and is bounded on the north and west by the Province of Ontario and on the south and east by the State of New York. It has a length of 185 miles, an average width of 40 miles, and, with its bays, a total area of about 7,300 square miles. There are no islands or shoals except near the outlet, where it discharges into the St. Lawrence River. The shores everywhere slope rapidly into deep water, but most rapidly on the south, and the deep trough runs nearer this shore. The 30-fathom contour on an average runs less than 3 miles from land on the southern shore, while on the north it is about 5 to 10 miles distant. The trough broadens toward the east and is overlaid by depths of 70 to 90 fathoms in the western half and by 90 to 123 fathoms in the eastern half. The bottom over most of the lake is clay with narrow stretches of sand and rock along the shores, particularly among the islands at the eastern end.

The lake's output is less than that of any of the others except Lake Nipigon, but in the early days fish seem to have been rather common in it. The annual yield has been about 5,000,000 pounds, most of it from the Canadian side. The principal species are whitefish, trout, and herring, with the coregonids predominating.

FISHING METHODS

The gill net is the type of apparatus most widely used on the Great Lakes. Gill nets of three sorts are in general use: (1) Nets of mesh of about 4 to 4¾ inches, stretched, though the mesh may be larger at certain seasons (these are used principally for whitefish and trout); (2) nets of 2 to 3 inch stretched mesh (these are employed chiefly for the lake herrings and chubs); (3) nets of about 1½-inch stretched mesh (used to take bait for the trout hooks).

Pound nets, with the related trap, crib, and fyke nets, are employed in the shore fisheries and take all the species that occur along the shores. All of them, of necessity, are restricted to use in shallow water and are therefore most numerous in those lakes where there are broad shoals. The use of certain varieties is proscribed within the jurisdiction of certain of the Governments that control the lakes.

Seines are now employed only in special fisheries and take few coregonids.

Hooks are used commonly in some of the lakes, principally for trout. Coregonids are never taken in commercial quantities by them.

For a more complete account of the fishing industry of the Great Lakes, consult Koelz, 1926.

COLLECTION OF DATA

Localities and Dates

In Tables 1 to 4 are given the localities visited in making collections and in gathering data for this paper, together with the periods of time during which the work was carried on and the number of lifts examined and specimens of each kind of fish preserved. While approximately 16 months were spent in the field, during only a fraction of this time was it possible to make observations. Much time was consumed in traveling from one port to another, and bad weather, especially in the fall, often prevented fishing operations for days at a time. During the entire period

many thousand pounds of fish were seen and examined, and a total of about 15,000 specimens was collected. These are mostly catalogued and preserved in the Museum of Zoology of the University of Michigan at Ann Arbor.

Field Methods

In the field it was my practice to be present when the nets were being lifted. In the case of the whitefish usually it was possible then to examine nearly every fish taken in the lift; but in the case of Leucichthys the individuals of a catch were far more numerous, so that it was possible to examine only samples of the catch. In any case these samples seldom comprised less than one-tenth of the catch and often (in the case of lifts under 1,000 pounds in weight) constituted half or more. The results of these examinations are given as applicable to the whole catch.

In addition to actual specimens, stomachs were collected also, chiefly on Lake Huron. These have been examined by Dr. Carl L. Hubbs, of the Museum of Zoology, University of Michigan, and his report is given under the heading "Food" for Lake Huron species.

At first fish were measured in the field, but as these measurements, of necessity, were made under such adverse conditions that it was not possible to check them, the practice was discontinued. Records of fish companies and log books of fishermen showing the weight and the locations of catches were copied wherever they could be obtained conveniently, and from every port the accounts of the habits of the various species of coregonids were recorded as given by the fishermen. Information of this kind has been secured through correspondence, also.

As a result of all the field work adequate material was made available on which to base conclusions regarding the systematic status of the various forms that occur in the Great Lakes. These conclusions from the study of specimens are supported by the accumulated field data dealing with the geographical and bathymetric distribution of these forms in the lakes, with their breeding grounds, breeding seasons, and their food.

EXPLANATION OF TERMS AND NOMENCLATURE

GLOSSARY

Measurements

All specimens collected were examined or reexamined in the laboratory. All measurements were made with fine dividers, calipers, a steel tape, and a wooden rule gauged in millimeters. The percentages and proportions used in the text or in the tables were arrived at by arithmetical calculation. The form of expressing the range of values is an arbitrary one. The usual values of a series given between the figures in parentheses (which are the extremes) represent, roughly, two-thirds of the individuals in that series. No series was subjected to statistical treatment because the number of individuals in none is adequate for refined analysis. All parts were measured and counted on the left side wherever possible. The method of making the measurements, the actual points from which measurements were made, and the symbols by which the measurements are designated in the tables and in Figure 8 are given below:

Length (L).—Measured from the junction of the premaxillaries to the end of the last vertebra. If the specimen was distorted, it was returned as nearly as possible to

its original shape. All measurements were made with dividers and then read on the rule, or the points marked by pins and measured with the tape.

Snout to dorsal (SD).—Measured from the junction of the premaxillaries to the base of the first dorsal ray.

Snout to anal (SA).—Measured from the junction of the premaxillaries to the base of the first anal ray.

Dorsal to adipose (DA).—Measured from the anterior end of the base of the dorsal fin to the anterior end of the base of the adipose.

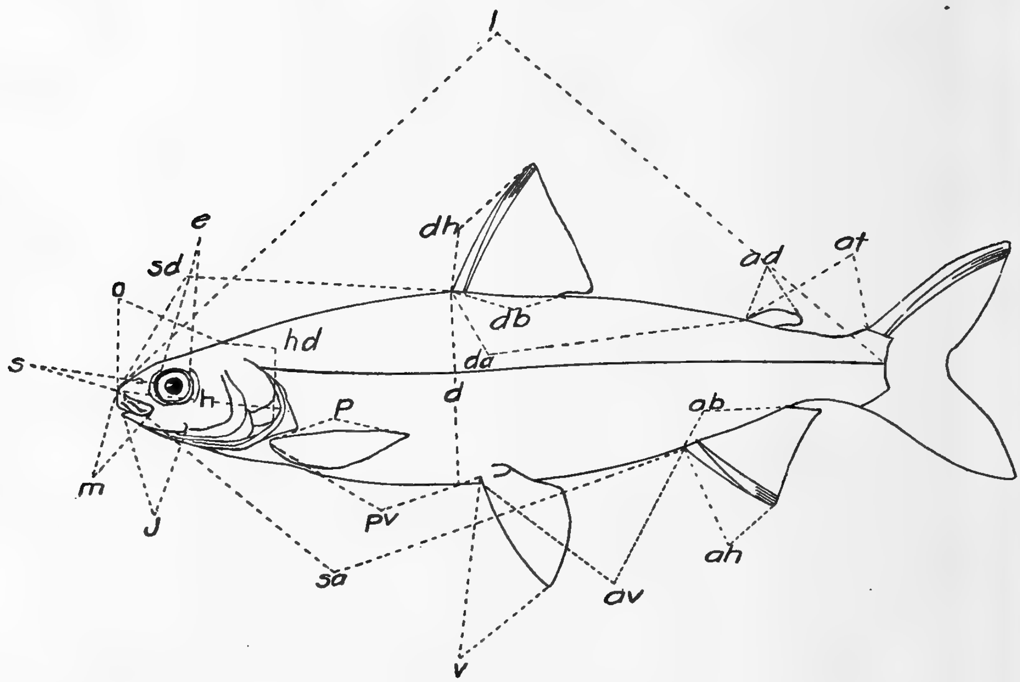

FIG. 8.—Outline of the whitefish, showing how the measurements referred to in the text and tables were taken

l—length	*p*—pectoral length	*m*—maxillary
sd—snout to dorsal	*v*—ventral length	*j*—mandible
sa—snout to anal	*ad*—adipose length	*e*—eye
da—dorsal to adipose	*db*—dorsal base	*av*—anal-ventral distance
at—adipose to caudal	*ab*—anal base	*d*—depth
h—head	*dh*—dorsal height	*hd*—head depth
o—occiput	*ah*—anal height	
s—snout	*pv*—pectoral-ventral distance	

Adipose to caudal (AT).—Measured from the anterior end of the adipose base to the first of the upper procurrent caudal rays.

Head (H).—Measured with dividers from the junction of the premaxillaries to the extreme bony margin of the operculum, not including the opercular membrane. This measurement, therefore, as given has not always been made parallel to the longitudinal axis of the body.

Head depth (HD).—Measured with dividers from the outer edge of the boundary between the suboperculum and interoperculum to the base of the occiput.

Occiput (O).—Measured from the junction of the premaxillaries to the end of the supraoccipital bone, not to the beginning of the scales. The exact point was determined by feeling with a sharp instrument.

Snout (S).—Measured from the junction of the premaxillaries to the anterior bony margin of the orbit. The dividers were inserted into the eye socket.

Maxillary (M).—This is in reality a measurement of the upper jaw and is taken from the symphysis of the premaxillaries to the caudal end of the maxillary bone.

Mandible (J).—Measured from the articulation of the articular with the cranium to the symphysis of the dentaries.

Eye (E).—The measurement given is the horizontal diameter of the eyeball, not the distance across the cornea. Dividers were inserted into the eye sockets and their points brought against the eyeball at the ends of its longitudinal axis. Care must be taken not to compress the ball in fitting the divider points.

Fin length (P, V, Ad).—Measured from the origin of the fin to the tip of its longest ray, or, in the case of the adipose, to its distal end.

Fin bases (DB, AB).—The length of the base of the dorsal and anal fins.

Dorsal coefficient (DC).—The height of the dorsal divided by its base.

Anal coefficient (AC).—The height of the anal divided by its base.

Pectoral-ventral distance (PV).—The distance between the anterior ends of the insertions of the pectoral and ventral fins.

Ventral-anal distance (AV).—Measured from the anterior end of the insertion of the ventral fin to the corresponding point of the anal.

Depth (D).—The greatest vertical depth of the body measured with calipers.

Width (W).—The greatest width of the body measured with calipers. In bloated specimens the width was taken in the region of the lateral line. This character is very unsatisfactory, inasmuch as the width of the body very frequently has been reduced by artificial compression in the preserved material.

Counts

Gill rakers (R).—The left arch, after being carefully removed with a sharp scalpel, was held completely spread out, and the counts were then made. (Care must be taken, in removing the arch, that no rakers are lost at the ends.) By this method the number of gill rakers on each part of the arch can be determined readily. Every visible raker has been included in the counts.

Scales in lateral line (SC).—In specimens with all their scales only those scales with pores were counted. In some specimens a few scales at the caudal end of the line lack pores. These have not been included in the counts. When scales had been lost accidentally from the lateral line, however, the scale pockets were counted throughout the entire length of the lateral line.

Longitudinal scale rows.—These were counted around the body at three locations—(1) just in front of the dorsal and ventral, (2) just in front of the adipose and the anus, and (3) around the caudal peduncle just behind the adipose and anal. The rows run lengthwise of the fish and can be counted easily except in the proximity of the fins. In front of the dorsal and adipose fins and behind the adipose and anal fins there frequently are developed very short rows, comprising sometimes only one or two scales All these were considered rows and were included in the counts.

Fin rays (DR, PR, VR, AR).—In the dorsal and anal fins the first one or two unbranched rays are poorly developed. Only when their length approached three-fourths that of the longest ray of the fin were they included in the count. Every ray in the pectoral and ventral fins was counted.

Vertebræ.—The flesh was removed from one entire side of the fish until the vertebral column was plainly exposed. Every vertebra was counted, including the last of the upturned ones at the base of the caudal fin.

Pyloric cæca.—The gut was removed and each cæcum picked off with the forceps. The count includes the cæca on the small intestine.

Branchiostegal rays (Br).—Every ray in the membrane was counted.

Miscellaneous Terms

Body.—Where the term "body" is used in the text it is meant to designate the body of the fish exclusive of the head.

Pearl organs.—These excrescences of the epidermis are developed only during the breeding season, often only in males. They attain their greatest development in the coregonids on the scales of the sides but also are evident on those of the other surfaces and usually on the head and fins.

SYSTEMATIC TREATMENT

In many groups of animals most of the species have been described already, and systematists, in turning their attention to the analysis of these species, have found that a species group is by no means so homogeneous as was supposed originally. It appears that most animals and their offspring, either from incapacity to do otherwise or from choice, breed in an area that, in comparison with the range of their species, is very restricted. Regional differences in structure or habit, associated with conditions of the environment, may be developed, therefore, and the animals of a species in certain localities may be distinguished by peculiar features. In the case of land animals it has been current practice to call these geographic races or varieties subspecies. Some species appear to be more plastic than others, and the number of subspecies that has been recognized in some species groups has reached a confusing total. Though it has been apparent that in certain widely separated regions the same sort of changes often were exhibited by the species of an animal group (for example, the coastal areas of British Columbia and Labrador are inhabited by several races of widely distributed birds that are darker than their relatives of the same species elsewhere), the changes are not identical throughout; and in general it is not known to happen commonly that two intraspecific groups of animals alike in their external features occur in geographically separated areas. In other words, the range of a terrestrial subspecies is considered continuous, and a subspecific name has a geographic connotation.

As a matter of fact, probably no species has a strictly continuous range. Its distribution depends on the distribution of suitable areas within the broad limits of its range. Thus, animals that inhabit swamps are found only where in their range swamps occur, and one such swamp may be separated by a vast distance from another.

To be sure, in mountainous areas, where altitude alters the natural effects of latitude, and in insular areas like habitats may be markedly disconnected and the

ranges of a morphologically distinct race likewise may be interrupted. Where these areas of similarity are not widely separated geographically or, geologically speaking, in time, the distinctive races may be considered subspecies, as usually their relationships with other members of the species group is clear even though they are so separated from them that there is no possibility of finding intermediate forms, which ideally is the criterion of a subspecies. But where like areas are widely separated in space and time, even though the forms in each may be nearly identical in structure and habit, taxonomists generally have preferred to consider them species rather than subspecies.

In aquatic habitats such zoogeographical islands also may occur; in fact, lakes are particularly good examples of isolated habitats. Though the types of lakes vary within certain limits, it is also true that aquatic habitats are simpler, in general, than terrestrial ones; they are influenced by fewer variables. Land habitats vary more because of differences in humidity, temperature, light, soil, elevation, etc. In aquatic environments humidity is not a variable, and temperature is limited in temperate regions between 0° and 25° or 30° C. At depths temperature differences are even eliminated, as are those of illumination. There remain differences in the chemistry of the water, depending on the soil of the basin, in depths, and exposure to wind. Where variables like temperature are not involved, the ordinary effect of latitude, which is so important in the distribution of land animals, is minimized; and, of course, where factors are few, the chances of finding them frequently in like combinations are greatest. It is thus possible to find in a lake in Indiana, as far as certain species are concerned, the same sort of habitat as in a lake in Canada 500 miles farther north; and it is likewise possible that two lakes in the same township may be so totally different in their physical conditions that their fish populations are very dissimilar. Now, in a given species the same mutation has a tendency to recur with a somewhat definite frequency. If it marks a higher degree of habitat adaptation than its parent in one place, and therefore tends to supersede its parent, it is only natural to expect the same outcome in another location where the environment is the same. It should not be surprising, then, to find varieties of a species of fish distributed according to the type of habitat rather than according to geographic zones.

The forms of the Great Lakes whitefishes thus appear to be distributed. The deep-bodied type of herring (*Leucichthys artedi*) is distributed here and there in lakes between New York and Manitoba, while in other lakes in this area the other extreme in development possible to this species may occur. Where two morphologically distinct forms of a species occur in the same lake, both extremes may be found in the area of intergradation, whether as a result of migration or of Mendelian segregation of interbred characters.

Botanists are confronted regularly with the irregular distribution of morphologically distinct individuals in the case of certain species of plants and find it convenient to introduce the terms "variety" and "form" in their nomenclature as units ranking less than a subspecies. In the case of the whitefishes it might be desirable, for certain reasons, to follow botanical practice; but, on the other hand, it is also desirable to keep the question of zoological nomenclature as simple as possible, and it is already sufficiently complicated by the use of trinomials. There seems to be on

possibility of standardizing these new terms when systematists are not even agreed as to the definition of a "species" or even of a "genus." An understanding of relationships between the various morphological forms depends on experimental breeding, which is often impracticable; and even where it is not, the results of such breeding may not leave the experimenter much the wiser. After all, a scientific name is regarded best only as a name. When its originator attempts to describe either the characteristics of the group of animals it stands for or to reflect in it his opinion of the origin or relationships of that group he meets with difficulties in expressing himself within the codes of nomenclatural standards.

I use here a subspecific name to designate individuals or a group of individuals that are distinct, morphologically, from a similar group of other individuals of the same species, regardless of what the relative distribution in space of those individuals or groups may be. Thus, two subspecies may be represented in the same school or a subspecies may be scattered throughout the range of its species group.

I believe that the whitefishes offer no unique problem in the field of zoological nomenclature. Certainly many other species of widely distributed fishes will be found to exhibit the same phenomenon of irregularly distributed morphological forms when they are studied in the same way, and workers in other fields of classification already are finding, with every addition to knowledge of the variations of animals, the insufficiency of a subspecific concept that is restricted to one geographical unit.

SYSTEMATIC HISTORY OF THE AMERICAN COREGONIDS

The genus Coregonus was established by Linnæus. For a century afterwards its species were a stumblingblock to the taxonomists of Europe. Apparently on account of faulty analyses, as well as of inadequate descriptions, these early systematists failed to distinguish clearly between the various forms. So confused and vague is much of this work that often it is not even mentioned in later revisions. Through accumulated knowledge of the morphology and natural history of the various coregonids and through a better comprehension of the relationships of other groups of fishes taxonomists of more recent times have been able to make progress in the classification of these fishes. To understand to what extent the representatives of the group have been confused it is only necessary to examine the synonomy of the species given by Regan (1908) for the forms of the British Isles, by Smitt (1895) for the Scandinavian forms, by Fatio (1890) for those of Switzerland, and by Berg (1916) for those of the old Russian Empire.

The present situation in North America is much the same as in Europe. The work done has been pioneer in character and the specific descriptions, for the most part, have been based on but few specimens, often from a single locality. No really extensive studies have been made hitherto of the variations that the various forms exhibit, and the systematic work has not been checked adequately by biological data; consequently species have been multiplied and confounded. All the works on North American coregonids in which new species have been described or in which existing descriptions have been revised are abstracted briefly in the succeeding paragraphs.

Under the synonomy of each species treated in the main body of this report are given only the first description of the species or redescriptions under another name

and references to it in only the two reviews of the coregonid fauna of North America—those by Evermann and Smith (1896) and Jordan and Evermann (1911) and in that of Dymond (1926) for Lake Nipigon. Few of the other works on these fishes have been critical, and often it is impossible to determine to what species the accounts refer. A more or less complete list of works containing other references to Great Lakes coregonids is appended in the bibliography.

References to the whitefishes are to be found in the earliest literature dealing with the Great Lakes region, namely, in the "Relations," of the Jesuit fathers. As early as 1634 Paul le Jeune mentioned the whitefish in the Canadian waters; and in the "Relation" of 1669 and 1670 Father d'Ablon described the method of capturing the whitefish (*clupeaformis*) at the Sault of Sainte Marie. He added that, on account of the custom of the natives to linger along the rapids for the purpose of fishing the whitefish, a mission was established at this place. He said further that a great many herring (*artedi*), which were much like those of the sea in shape and size but were not quite as good for food, were taken in Superior, particularly in November. Explorers of the eighteenth century (Charlevoix, Hennepin, Lahontan, and others), also spoke of the whitefish and attested to its fine qualities as a food fish.

Pennant (1792) was the first zoologist to record an American species of Coregonus. He stated (on p. 298) that "*Salmo laveretus* or *gwiniad* is found in Hudson Bay in vast abundance." He added that "there is a lesser kind called the Sea Gwiniad," which he describes briefly. Richardson (1823), said these fish undoubtedly were *C. clupeaformis* and *P. quadrilaterale,* for the reason that no other fish of similar appearance or habit were known from the area that Pennant visited. A later mention of the whitefish, which antedated the first description by about three years, was made by DeWitt Clinton in a letter to S. L. Mitchill, dated February 1, 1815. He said in this letter that the whitefish is the most delicious of the fishes in the western waters and that it must be a nondescript Salmo, judging from the account he received of its form and habitudes.

Dr. S. L. Mitchill (1818) described the whitefish, which he called *Salmo clupeaformis,*[1] whitefish of the lakes. The description is based on a specimen obtained from the falls of St. Mary at the northern extremity of Lake Huron, and is the first scientific description of an American Coregonus. While the description is not adequate, and was supposed, for many years afterward, to refer to *artedi,* it seems safe to assume that Mitchill actually had the whitefish. The review of the remaining literature on American forms follows in chronological order.

LeSueur, C. A., 1818.—Inadequate descriptions of two coregonids are given—*Coregonus artedi* and *C. albus.* The latter is figured. The two fish thus described are lake herring. As they were taken from Lake Erie (though the former was said to occur in the Niagara River also), LeSueur must have had in hand the two types of herring that are known to occur there—the blueback, which is found in the other lakes, and the cisco, a fatter and broader variety, which is abundant in Lake Erie. It has been supposed by many ichthyologists, erroneously, that LeSueur had the true whitefish (the Erie form of *clupeaformis*) in mind when describing *albus,* and consequently the name *albus* has been associated with this form. A study of the original account indicates that this is not likely, even though LeSueur did say that *albus* was called the whitefish. He says, for example, "This species differs from the preceding one (*artedi*) in its body having more depth, its back a greater

[1] This name has been altered frequently to the classically correct form *clupeiformis.*

elevation, and its proportions much stronger in body, fins, and scales." He records no difference in the shape of the snout, which for *artedi* is "pointed." The figure of *albus* made by LeSueur himself is distinctly not a Coregonus.

Richardson, John, 1823.—*Coregonus quadrilateralis* from "the small rivers about Fort Enterprise and in the Arctic Sea" is described. The description is recognizable and is accompanied by a crude cut. A fish is described as *C. albus*, which is undoubtedly the whitefish, and the tullibee is mentioned under the name *C. artedi* ?.

Richardson, John, 1836.—On page 201 of this publication (Fauna Boreali-Americana, Vol. III) is given a description of *Salmo* (*Coregonus*) *tullibee* from Cumberland House, Pine Island Lake, latitude 54° N., and on page 204 *quadrilateralis* from Great Bear Lake, latitude 64½° N. is more fully described and better figured than in the preceding publication. In the same volume are described (on p. 206) *labradoricus* from Musquaw River, Gulf of St. Lawrence, (on p. 207) *lucidus* from Great Bear Lake, and (on p. 210) *harengus* from Penetanguishene in Georgian Bay, Lake Huron. All but *tullibee* and *labradoricus* are figured.

Storer, D. H., 1846.—Storer gives a list of the North American coregonids that had been described up to 1846, together with the synonomy of each.

Agassiz, Louis, 1850.—In this work the name Argyrosomus was first proposed to designate the whitefishes having the lower jaw longer than the upper, in contrast with the true Coregonus, with a truncated snout and included lower jaw. The name Argyrosomus was already occupied and has been replaced provisionally by Jordan and Evermann with Dybowski's Leucichthys. Two new species from Lake Superior, *Coregonus sapidissimus* and *latior*, are described, but neither is valid.

Prescott, W., 1851.—Two new species of Coregonus are described from Lake Winnepesaukee, N. H.—*neo-hantoniensis* and *nov-angliæ*. These have been considered subsequently as synonyms of *clupeaformis* and *quadrilaterale*.

Girard, Charles, 1856.—A species of Coregonus from Des Chutes River, Oreg., is described inadequately as *williamsoni*.

Günther, Albert, 1866.—All American forms are described with synonomy and a description of *C. richardsonii*, from "Arctic North America," is given for the first time.

Hoy, P. R., 1872.—Hoy makes mention of two species of Argyrosomus, of which he had sent specimens to Gill and which Gill named *hoyi* and *nigripinnis* but did not describe. While Hoy gives no technical description of either fish, and only two mutilated specimens, both of which are labelled *hoyi*, are preserved in the United States National Museum, it is certain that the fish Hoy referred to as *nigripinnis* is the blackfin. He says of it that it has black fins and lives off Racine in water over 60 fathoms in depth. The two specimens, 5½ and 7¼ inches long without the caudal (catalogue No. 8902, U. S. National Museum), are called "mooneyes" in his account. Of the "mooneye" he says that it is the smallest of the whitefishes, being only about 8 inches long, and is found in water over 40 fathoms deep. Hoy's specimens are too small to have been gilled in the commercial nets and were, according to the statement of Charles Hyttel, sr., who furnished them to Doctor Hoy, brought in with the bloaters and a few immature chubs that had entangled their jaws in the nets. As the bloater is the only species commonly caught in this way, it is likely that Hoy had this fish in mind as the "mooneye." One of the specimens (No. 8902) is a bloater and has been selected by me as the type; the other is a chub, either *alpenæ*, *reighardi*, or *zenithicus*. The only description of *hoyi* based on Hoy's specimens was made by Hugh M. Smith (1894). Smith, however, did not recognize the fact that the two fish were not of the same species and apparently based his description on both.

Milner, J. W., 1874a.[2]—On page 86 Milner describes *Argyrosomus hoyi*, *A. nigripinnis*, and *Coregonus couesii*. *Hoyi* and *nigripinnis* had been named by Doctor Gill and mentioned by Hoy in 1872. Milner's *nigripinnis* is from Lake Michigan and is the same fish referred to by Hoy. *Hoyi* is described from Lake Superior, but the description is wholly insufficient. Under the United States National Museum catalogue No. 10576 (not 10756, as given in Milner's text) are entered the three specimens of Milner's account—two specimens of *zenithicus* and one of *hoyi*. The description

[2] H. M. Smith, Bulletin, U. S. Fish Commission for 1894, Vol. XIV, on p. 7, says: "The report was certainly not issued in 1874 * * * and the indications are that the report was not printed before May or June, 1875."

given by Milner apparently involves both species. *C. couesii* is a whitefish taken in Chief Mountain Lake at the head of the Saskatchewan River.

Jordan, D. S., 1875.—A description, accompanied by a crude figure, is given of *Argyrosomus sisco* from Lake Tippecanoe, Kosciusko County, Ind. This species is compared with a fish that the author calls *A. hoyi*, a name based not on the specimens of Gill and Hoy but on another fish sent by Hoy to Jordan. This fish probably was the Lake Michigan representative of *zenithicus*, which Jordan, in his subsequent writings, seems to have had in mind as *hoyi*. This paper was abstracted in the same year in the American Naturalist.

Jordan, D. S., 1878.—Seven species and four possible varieties of whitefishes are mentioned on pages 274 to 276. The interest of this work lies in the subgeneric divisions, which are outlined on pages 360 to 362. Prosopium is published from Milner's manuscript as a generic designation for whitefishes of the *quadrilateralis* type.

Bean, T. H., 1881a.—Coregonus laurettæ is described as a new species on the basis of four specimens taken at Point Barrow and one at Port Clarence, Alaska.

Jordan, D. S., and C. H. Gilbert, 1882.—This account condenses the species that previously had been described for North America to the following: *Coregonus couesi* (Milner), *C. williamsoni* (Girard), *C. quadrilateralis* (Richardson), *C. clupeiformis* (Mitchill), *C. labradoricus* (Richardson), *C. hoyi* (Jordan), *C. artedi* (LeSueur), *C. nigripinnis* (Gill), *C. tullibee* (Richardson). In addition to these, *C. kennicotti*, from Fort Good Hope, British America, and Yukon River, Alaska, is included from Milner's manuscript; and *C. merki* (Günther), from the Bering Sea to the north shore of Siberia, is added to the North American fauna.

Bean, T. H., 1884a.—Coregonus nelsonii is described as a new species. It is said to occur only in Alaska from the Bristol Bay region northward. The type is from Nulato.

Bean, T. H., 1888.—Coregonus pusillus was referred to by the author in Proceedings, United States National Museum, volume 4, 1881, page 256, as an unnamed variety of *C. merki* and is described from a specimen collected in Putnam or Kuwuk River, Alaska.

Bollman, Charles H., 1889.—Bisselli, from Rawson and Howard Lakes, Mich., is described as a new subspecies of *Coregonus tullibee.*

Jordan, D. S., 1891.—Cismontanus, from the Madison River, Mont., is described as a new subspecies of *Coregonus williamsoni*. Two figures accompany the text.

Eigenmann, C. H., and R. S. Eigenmann, 1892.—A description is given of *Coregonus coulterii* based on over 100 specimens from Kicking Horse River, Field, British Columbia.

Smith, H. M., 1894.—Coregonus osmeriformis is described and figured from Seneca and Skaneateles Lakes, N. Y., and *Coregonus prognathus* from Lake Ontario off Wilson, N. Y. The synonomy of *hoyi* is discussed, and a figure and description obviously based on the two fish sent by Hoy are added.

Evermann, B. W., and H. M. Smith, 1896.—No new species are described but the accounts given in this publication are more detailed than in any previous or subsequent publication. The previously described forms for North America are reduced to 20 species and subspecies: *Coregonus coulterii, C. williamsoni, C. williamsoni cismontanus, C. kennicotti, C. richardsonii, C. quadrilateralis, C. clupeiformis, C. nelsonii, C. labradoricus, Argyrosomus osmeriformis, A. artedi, A. artedi sisco, A. hoyi, A. pusillus, A. lucidus, A. laurettæ, A. prognathus, A. nigripinnis, A. tullibee*, and *A. tullibee bisselli.* All but *C. richardsonii, A. artedi sisco*, and *A. tullibee bisselli* are illustrated by pen drawings.

Jordan, D. S., and B. W. Evermann, 1896.—All the known species of the lake herrings and whitefishes, together with their synonomy, are listed under two genera—Coregonus subgenera Coregonus and Prosopium, and Argyrosomus subgenera Argyrosomus and Allosomus. The species of Prosopium are *coulterii, williamsoni, w. cismontanus, kennicotti, richardsonii*, and *quadrilateralis;* the species of Coregonus are *clupeiformis, nelsonii*, and *labradoricus;* the species of Argyrosomus are *osmeriformis, artedi, a. sisco, hoyi, pusillus, lucidus, laurettæ, prognathus*, and *nigripinnis;* and of Allosomus the species are *tullibee* and *t. bisselli.*

Scofield, N. B., 1899.—Argyrosomus alascanus (Scofield) from Point Hope and Grantley Harbor, Alaska, is published as a new species from Scofield's manuscript, which appeared subsequently in D. S. Jordan, "The fur seals and fur-seal islands of the North Pacific Ocean," part 3, 1899.

Kendall, W. C., 1903.—Coregonus stanleyi from the thoroughfare between Mud and Cross Lakes, Me., is described and figured as a new species.

Jordan, D. S., and B. W. Evermann, 1909.—Argyrosomus eriensis and *huronius* from Port Stanley, Lake Erie, and *A. zenithicus* from Duluth, Lake Superior, are described and figured. The synonomy of *clupeaformis* and *albus* is appended.

Jordan, D. S., and J. O. Snyder, 1909.—Coregonus oregonius is described from the McKenzie River, Oreg. The species was included in part in the description of *C. williamsoni* by N. B. Scofield, 1899, page 463.

Wagner, George, 1910.—Argyrosomus johannæ is described from specimens secured in Lake Michigan some 18 miles out from Racine, Wis., at a depth of 25 fathoms.

Jordan, D. S., and B. W. Evermann, 1911.—Most of the literature on the coregonids is reviewed and the species in the Great Lakes redescribed. Five new forms of Leucichthys are added to the fauna—*supernas* and *harengus arcturus* from Lake Superior near Duluth, *cyanopterus* from Lake Superior off Marquette, *manitoulinus* from the North Channel off Blind River, and *ontariensis* from Lake Ontario off Deseronto. All the Great Lakes species except *prognathus* are figured. Six of the illustrations are from paintings.

Wagner, George, 1911.—Leucichthys birgei is described from Green Lake, Wis.

Bean, T. H., 1916.—Leucichthys macropterus is described from a specimen obtained in Lake Erie.

Harper, F., and J. T. Nichols, 1919.—Of the six species described, four are whitefishes—*Coregonus preblei* from Tazin River, about 1 mile above its confluence with the Taltson River, Mackenzie, Canada (with photograph); *Leucichthys entomophagus* from Tazin River, Mackenzie, Canada; *L. athabascæ* from Lake Athabasca, at the mouth of Charlot River, northern Saskatchewan, Canada; and *L. macrognathus* from the shore waters of Great Slave Lake, near Fort Resolution, Mackenzie, Canada.

Jordan, D. S., 1918.—The genus Irillion is proposed with *Coregonus oregonius* as the type.

Snyder, J. O., 1919.—Leucichthys gemmifer, Coregonus spilonotus, and *Coregonus abyssicola* are described from specimens secured in Bear Lake near Fish Haven, Idaho. Each species is figured.

Koelz, W., 1921.—Leucichthys kiyi is described as a new species from Lake Michigan off Sturgeon Bay, Wis.

Koelz, W., 1924.—Leucichthys alpenæ is described from Lake Michigan off Charlevoix, Mich., and *Leucichthys reighardi* from off Michigan City, Ind.

Koelz, W., 1925.—Leucichthys nipigon is described from Lake Nipigon.

Dymond, J. R., 1926.—A very good systematic account is given of the species of Coregonidæ that inhabit Lake Nipigon.

Hubbs, C. L., 1926.—In this check list a preliminary outline is given of the systematic arrangement of coregonids followed in this paper.

VARIABILITY AND DETERMINATION OF SPECIES IN THE GREAT LAKES COREGONIDS

GENERAL STATEMENT

Smitt (1895, p. 827) says of the Salmonidæ (which in his arrangement include the coregonids), "there is hardly any other part of the system where the scientist is confronted with such difficulties in defining the limits of the species." Any systematist who knows the Salmonidæ, or only the Coregonidæ, will agree with Smitt. The descriptions of the coregonids in the early days of taxonomy were very vague and were simply general remarks about shape, size, and color; or, if they were more specific, they emphasized insignificant details. The best workers of the nineteenth century, up to 1882, confined themselves in their diagnoses to purely external characters. Nüsslin (1882) calls attention to this fact and cites as an example the work of Nilsson, Cuvier and Valenciennes, Siebold, and Günther. He shows that two

forms that had been considered identical have different numbers of gill rakers. He points out the specific importance of the shape of the snout, the number of gill rakers, and of biological data. Later workers on the coregonids have paid heed to Nüsslin but still have given too much weight in their diagnoses to differences in proportions and other similar characters which may be influenced by the environment. In fact, little effort has been made to determine, by a study of the variability of the external characters, what relation, if any, existed between them and the environment.

VARIABILITY OF INDIVIDUAL CHARACTERS

My own work on the forms in the Great Lakes, based on measurements of some 10,000 specimens from many localities and cursory inspection of some hundreds of thousands, has involved, then, of necessity, an attempt at analysis of the variability of these forms. The effort has been made to study all possible characters in order to learn which ones so vary that they are of little or no use in classification and which ones are sufficiently stable to be of use. At the same time the available data on spawning seasons, bathymetric and geographic distribution, seasonal movements, and other biological factors have been studied in order to learn whether they are correlated with the structural characters found usable in classification.

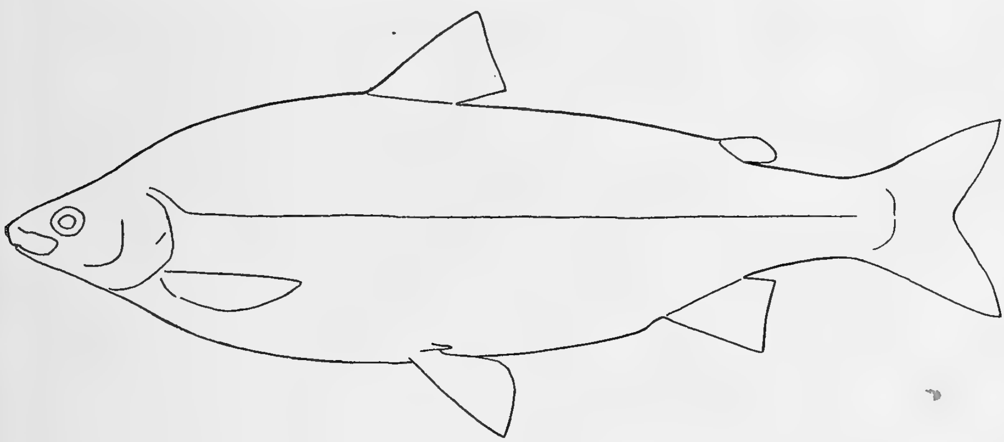

FIG. 9.—Body outline of the typical Lake Erie whitefish

Body Contour

Leucichthys.—Two groups may be separated according to contour or form of body as seen from the side. In the first of these the body is more or less perfectly elliptical. The species included are *alpenæ*, *zenithicus*, *reighardi*, *hoyi*, *artedi*, and *nipigon*. Of these, *hoyi*, *reighardi*, *nipigon*, and the *albus* and *manitoulinus* subspecies of *artedi* are least elongated and the typical *artedi* is most elongated. In the second group, comprising *johannæ*, *nigripinnis*, and *kiyi*, the anterior dorsal profile rises rapidly for two-thirds its extent and continues thence to the dorsal fin as a nearly horizontal line. In *nigripinnis* the anterior ventral profile extends in a direction similar to the dorsal, so that the anterior half of the body in this species is distinctly the deeper. In *johannæ* the tendency of the contour line between the dorsal and the adipose to become straight further interrupts the symmetry of the lateral profile.

All the above are compressed laterally, but the degree of compression is least in typical *artedi* and typical *reighardi*.

Coregonus.—The body of *clupeaformis* is most like that of *johannæ* in outline.

Prosopium.—The body of *quadrilaterale* is an elongated ellipse in outline, as in the first group of *Leucichthys*, but the body is nearly terete.

Length

The coregonid forms in the Great Lakes have about the same average and maximum lengths. The range in size of specimens seen by me is shown by the dimensions below. From this it appears that the maximum lengths of *Coregonus clupeaformis* and of the smallest species of Leucichthys (*hoyi* and *kiyi*) only are very different from those of the rest and would be of value in discriminating certain specimens of these species. It appears, further, that the maximum lengths known for each species from the various lakes also are very similar.

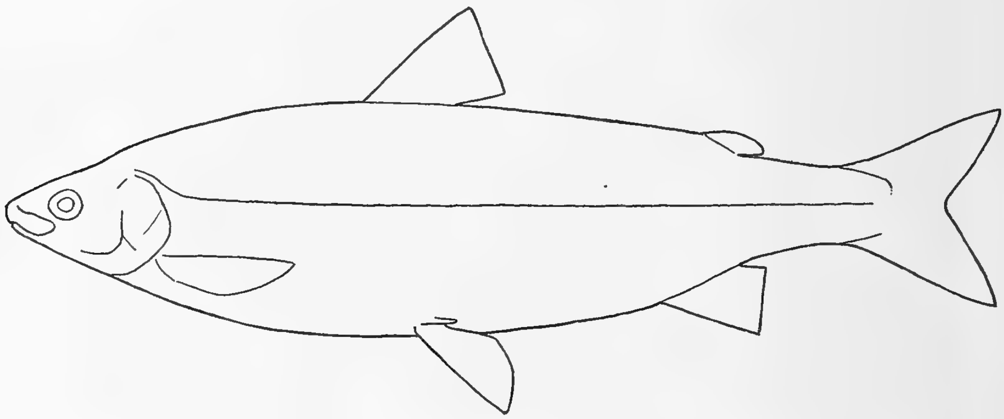

FIG. 10.—Body outline of the type of whitefish common in the upper lakes

Species	Lake	Range in length, in millimeters	Species	Lake	Range in length, in millimeters
Leucichthys johannæ	Michigan	181–288	L. hoyi	Michigan	82–265
Do	Huron	132–332	Do	Huron	79–221
L. alpenæ	Michigan	130–386	Do	Superior	107–251
Do	Huron	131–368	Do	Nipigon	106–231
L. zenithicus	Superior	134–332	Do	Ontario	128–277
Do	Nipigon	153–308	L. artedi	Erie	128–402
Do	Michigan	152–312	Do	Michigan	127–367
Do	Huron	139–318	Do	Huron	125–371
L. reighardi	Michigan	144–278	Do	Superior	135–435
Do	Superior	203–320	Do	Nipigon	138–253
Do	Nipigon	145–304	Do	Ontario	155–366
Do	Ontario	203–295	L. nipigon	Nipigon	220–447
L. nigripinnis	Michigan	220–360	Coregonus clupeaformis	Michigan	179 mm. to 6 lbs.
Do	Huron	208–371	Do	Huron	192 mm. to 15 lbs.
Do	Superior	198–375	Do	Superior	180 mm. to 6 lbs.
Do	Nipigon	141–355	Do	Nipigon	203 mm. to 4 lbs.
Do	Ontario	297	Do	Erie	291 mm. to 5 lbs.
L. kiyi	Michigan	122–245	Do	Ontario	253 mm. to 6 lbs.
Do	Huron	105–249	Prosopium quadrilaterale	Michigan	156–419
Do	Superior	132–204	Do	Huron	176–393
Do	Ontario	148–263	Do	Superior	65–380
			Do	Nipigon	191–318
			Do	Ontario	213–361

Depth and Width

Depth and width measurements of the body can not be recorded satisfactorily for specimens of coregonids, because those coming from the deeper waters are always

bloated, sometimes even burst, and because the softness of the flesh of the individuals of the species renders it very difficult to preserve the shape properly during the period of collection. These characters also change proportionally during the growth of the individual, all young fish of the group having frailer bodies than the adults. The relative width and depth of the body, therefore, is variable for each species, and for none of the species is it a distinguishing character. In certain species the body depth varies relatively much more than in others. In the case of the lake herring (*L. artedi*) the several varieties are differentiated sharply by the relative depth of the body. In the typical *artedi* L/D is higher, on the whole, than for any other coregonid in the basin, while for the *albus* type occurring in the same lake it may be as low as or lower than that of any other coregonid. The races of *reighardi, nigripinnis,* and *clupeaformis* also are differentiated in part by variation in this character.

Scales in the Lateral Line

The number of scales in the lateral line is variable within a species and even within a race. It may be seen from Table 7 that the extremes are much the same for the various species in each lake. In most of the lakes *quadrilaterale,* with the maximum number of scales, is more or less distinctly separated only from *hoyi,* which has the smallest number; though in Lake Nipigon, where most of the species of Leucichthys have relatively few scales, it is probable that the scale count usually would be a generic distinction between Leucichthys and Prosopium. However, the usual number of scales is rather different for the various coregonids in each lake.

The usual number of scales also is more or less different for most of the geographically separated forms of each species. As has been pointed out above, all the races of Leucichthys occurring in Lake Nipigon have fewer scales on the average than those from other lakes, except the race of the species *hoyi,* which tends to have more than its relatives. The Huron forms of *johannæ, nigripinnis, kiyi* and *quadrilaterale,* the Superior form of *kiyi,* and the Erie form of *clupeaformis* also seem to have somewhat fewer scales than the Michigan forms of these species. The subspecies of *artedi* may differ conspicuously in the character, as is illustrated by the *manitoulinus* form of Huron and the *albus* subspecies of Superior and Erie.

Scale Rows

The number of longitudinal scale rows around the body also is variable within a species and within a race. Below are given the comparative values for the forms of Lake Michigan. A similar table for the other lakes would show about the same relation between the counts.

Species	Number in front of dorsal and ventrals	Number in front of adipose and anal	Number around caudal peduncle
Leucichthys:			
johannæ	(38) 41–44 (46)	(31) 33–37 (38)	(22) 24–26 (27)
alpenæ	(40) 41–43 (45)	(30) 33–35 (36)	(23) 24–26 (27)
zenithicus	40–42 (46)	(30) 32–34 (36)	(23) 24–25 (26)
reighardi	(38) 40–43 (46)	(30) 32–35 (39)	22–24 (26)
nigripinnis	(41) 42–44 (45)	(32) 33–35 (36)	(23) 24–26 (27)
kiyi	(39) 41–44 (46)	(32) 33–35 (37)	(23) 24–25 (26)
hoyi	(38) 40–42 (44)	(31) 32–34 (35)	(22) 23–25 (26)
artedi	(39) 43–46 (49)	(32) 34–37 (38)	(23) 24–26 (27)
nipigon [1]	(41) 43–45	(32) 33–34 (35)	(23) 24–25 (27)
Coregonus clupeaformis	(46) 48–50 (52)	(36) 37–39 (40)	25–27 (28)
Prosopium quadrilaterale	(40) 42–45 (46)	(31) 33–35 (36)	(24) 25–27 (28)

[1] Lake Nipigon specimens.

It appears that only *clupeaformis* and *hoyi* have a distinctive number of scale rows—the one with the highest, the other with the lowest count. The range of both, however, overlaps, more or less, that of at least some of the other species. Within each species there may be variations in the number of scale rows in the various lakes and among the several races within the same lake. Thus, *johannæ* has fewer scale rows in Huron than in Michigan; *zenithicus, reighardi, nigripinnis,* and *hoyi* have fewer in Nipigon; *hoyi* has slightly fewer in Superior than in the other lakes; the predominant *artedi* of Erie, Ontario, and Nipigon have fewer rows than the predominating herring races of the other lakes; and the Erie whitefish has fewer than the whitefish of the other lakes. The *manitoulinus* subspecies in Huron has many fewer rows than the *artedi* subspecies, and the *albus* subspecies of Erie has fewer than the *artedi* form in that lake. This is true also of these two races in Lake Superior. It seems, in general, that the number of scale rows varies directly with the number of lateral-line scales.

Pearl Organs

Pearl organs are present during the breeding season in at least the males of each species. Not enough material is available to determine to what extent this character is of systematic importance to separate the species, but it appears that it will separate the three groups. In Leucichthys pearls are present on the head as well as on the sides of the body and are of virtually uniform thickness. They have been found well developed only in males. In Coregonus they are distributed more or less as in Leucichthys but are present on males and females and are conspicuously thicker in the middle. All the specimens of Prosopium seen differ from Leucichthys and Coregonus in having no pearls on the head. The form of the pearl is approximately as in Coregonus, and both males and females have pearls.

Fins

DORSAL

The ratio between the height of the dorsal and its base (the dorsal coefficient of the tables) is variable in all species and even in all races. There are no distinguishing features about this character, but it is interesting to point out that the dorsal base appears to average longest, relatively, in the various races of *clupeaformis, quadrilaterale,* and *artedi,* and shortest, relatively, in *hoyi* and *kiyi.*

The number of dorsal rays also is not distinctive except possibly between the forms with extreme numbers. *Quadrilaterale,* which has the highest number (11 to 13), overlaps but seldom the range of *hoyi,* with usually 9 or 10. *Kiyi* and *reighardi* also usually have a low dorsal ray count.

The number of rays seems to vary among the races of a species as well. Thus, the Superior and Nipigon forms of *reighardi* have more dorsal rays, on the average, than the typical form. *Hoyi,* in Nipigon, tends to have a greater number than the forms elsewhere in the Great Lakes.

ANAL

The anal coefficient is variable and distinguishes only Prosopium absolutely from most of the species of Leucichthys. The anal base is relatively shortest in *quadrilaterale, hoyi,* and *kiyi* and longest in *johannæ* and *artedi.* In the Leucichthys

species (except *hoyi* and *kiyi*) the AC value frequently is less than 1, while in these species and in *clupeaformis* and *quadrilaterale* the value usually is more than 1.

The number of anal rays also is variable and is distinctive in none of the forms. The usual number is 10 to 12 but may vary within the species. Thus, *reighardi* of Superior has slightly more rays than the typical race.

PECTORALS

The length of the pectorals in relation to the pectoral-ventral distance is of systematic importance, but none of the species are absolutely separable by this character, as may be seen in Table 10. The races of *kiyi* have relatively the longest pectorals and those of *reighardi* the shortest.

Within each species there is enormous variation in this character. Thus, the pectorals of the Huron race of *johannæ* average longer than those of the Michigan race; in *zenithicus* they are shorter in Michigan and Huron than in Superior and Nipigon; in *reighardi* they are longer in Superior and Nipigon than in Michigan and Ontario; in *nigripinnis* they are longer in Huron and Nipigon than in Michigan and Superior; in *kiyi* they are longer in Superior and shorter in Ontario than in Michigan and Huron; in *hoyi* they are longer in Nipigon, Superior, and Ontario than in the other lakes; in *artedi* the predominant race of Nipigon has longer pectorals than the predominant races in the other lakes; in *quadrilaterale* the pectorals are longer, on the average, in Superior and Huron than in Lake Michigan.

Within the same lake there are differences in the length of the pectorals in the case of the species *artedi*. The *manitoulinus* form in Huron has much longer pectorals than the *artedi* form, and in Lakes Superior and Erie the *albus* form has longer pectorals than the *artedi* form.

The number of pectoral rays is not distinctive, but some species tend to have a lower number, on the average, than others. Within the species, also, the number may vary. Thus, the *hoyi* of Ontario and the *clupeaformis* of Erie seem to have a lower average number than their relatives in the other lakes; and *johannæ* in Huron has more than in Michigan.

The shape of the pectoral often has some value as a systematic character. In typical *nigripinnis* and in *johannæ* the dorsal margin frequently is decurved and most frequently is relatively straight in other species.

VENTRALS

The relative length of the ventrals is of more systematic importance than that of the pectorals. (See Table 11.) They are longest in the *kiyi* and shortest in the races of *quadrilaterale*, *artedi*, and *clupeaformis*, but only the figures for the *kiyi* and the *quadrilaterale* are quite distinctive. The overlapping between the ranges of the *kiyi* and the *artedi* in the same lake usually is very slight, however.

The same variation occurs within the species as in the case of the pectorals, though it is not so extensive. In *zenithicus* the Michigan and Huron races seem to have somewhat shorter ventrals than those from other lakes; in *reighardi* they appear to be somewhat longer in Nipigon than in the others; in the case of *nigripinnis* they are somewhat longer in Huron; in *kiyi* they are shorter in Ontario and longer in

Superior; in *hoyi* they are longer in Nipigon and Superior than in the other lakes; in *quadrilaterale* the races of Superior and Michigan seem to have longer ventrals than the race of Lake Michigan.

Within the species of a lake it is evident that the same sort of variation in ventral length occurs as in pectoral length, as illustrated by the fact that the *manitoulinus* race of Lake Huron and the *albus* races of Lakes Superior and Erie have longer ventrals than the *artedi* races of these lakes.

The number of ventral rays does not appear to be characteristic of any species. The rays number from 10 to 12 in virtually all, though some more often have 10 than 12, and vice versa. There is also no conspicuous variation in this character within a species.

CAUDAL

There are no satisfactory ways of measuring the caudal; and while it appears that in the case of certain species this member may be more broadly forked, the eye may easily be deceived by the course of other contour lines in estimating the extent of the cleft. It is sufficient to point out that in no species is the tail fin conspicuously different in the extent of its development.

ADIPOSE

As may be seen from an examination of the Tables 17 to 101, the size of the adipose is extremely variable and has little value as a systematic character. The species of Coregonus seem to have a longer adipose than the species of the other genera, but this character is not always distinctive.

Caudal Peduncle

The length of the caudal peduncle, measured from the anterior end of the base of the adipose to the first caudal rays, is too variable within each species to have specific value. The depth has not been measured. For an expression of the proportion see column L/AT in Tables 17 to 101. It also appears to vary decidedly within a species. The deep-bodied forms, *manitoulinus* and *albus* of *Leucichthys artedi* (especially the former), have a shorter and relatively deeper caudal peduncle.

Flesh

The species within a lake are quite different in their food value. In this respect *artedi*, with its varieties, must be rated lowest and *clupeaformis* highest. *Prosopium quadrilaterale* and the other species of Leucichthys are intermediate, the first nearest to *artedi*, the last nearest to *clupeaformis*.

In Lake Nipigon none of the Leucichthys are yet marketable, so it is not known how much they will be esteemed.

The quality of flesh within a species also may be variable with the environment. Thus, Lake Superior whitefish may be most esteemed by some buyers, while others may prefer the Lake Erie product. The differences are nowhere as great as in the case of the Erie *artedi*, which has richer flesh than members of the species in the other lakes. It regularly competed in late years with the deep-water forms of Leucichthys or "chubs" of other lakes in the smoked-fish trade, and large individuals very often are sold as whitefish.

Color

Color, which in most groups of fishes serves as a character to separate even closely related species, is of little value in distinguishing between the species of coregonids in the Great Lakes. While faint color may be present in living fish, the fish die very soon after capture (in fact, the deep-water forms are dying when lifted from the nets), and after death the color fades very soon, leaving a nearly uniform silvery appearance to all the forms. In life Leucichthys and Coregonus are tinted with a green or blue-green, the intensity of the coloration varying with the species. It is deepest in the *artedi*, especially the *manitoulinus* form, and usually in *nigripinnis*, and in these forms (particularly the first two) may often become intensified for a short time after death. In life Prosopium differs strikingly from the rest in coloration. The blue-green of the others is replaced in *quadrilaterale* by a greenish bronze, and the sides have a decided pinkish cast.

Pigmentation also varies, and usually directly with color—that is, the fish with most intense colors usually have more pigment on the head, especially the anterior parts, and on the body and fins. *Manitoulinus* and most of the forms of *nigripinnis* are much more pigmented than any of the other forms.

The degree of pigmentation varies among the forms of a species. In *zenithicus* the Nipigon race is much paler and that of Michigan and Huron somewhat paler than the typical race; in *reighardi* the Nipigon race is much paler throughout than the typical Michigan form, while the forms of Superior and Ontario are somewhat less pigmented; the *nigripinnis* of Superior is paler than that of the other lakes; the *kiyi* of Ontario appears to be a trifle more pigmented than the races of the other lakes; the *hoyi* of Superior shows a little more pigment on the fins than the forms of the other lakes; the typical *artedi* form is darker than the *albus* form of *Leucichthys artedi*, and the *manitoulinus* form is darkest of all; the Lake Erie *clupeaformis* seems to be the palest of the races of Coregonus.

Vertebræ

The number of vertebræ in the vertebral column is given for a few individuals of each species, chiefly from Lake Huron.

Species	Number of specimens counted	Number of vertebræ	Species	Number of specimens counted	Number of vertebræ
Leucichthys:			Leucichthys—Continued.		
johannæ	11	57–60	hoyi	17	55–60
alpenæ	12	57–59	artedi	9	57–60
zenithicus	8	55–58	nipigon [2]	2	58–60
reighardi [1]	6	57–59	Coregonus clupeaformis	8	60–63
nigripinnis	8	58–60	Prosopium quadrilaterale	12	59–63
kiyi	10	57–59			

[1] Lake Michigan specimens. [2] Lake Nipigon specimens.

It appears that the number of vertebræ varies for each species and that, on the average, Leucichthys has a lower number than Coregonus or Prosopium.

Pyloric cæca

The number of pyloric appendages is rather variable within the species, but the averages show interesting differences in a few cases. They are counted below chiefly for specimens from Lake Huron.

Species	Number of specimens	Range	Species	Number of specimens	Range
Leucichthys:			Leucichthys—Continued.		
johannæ	8	142–222	hoyi	29	88–164
alpenæ	6	126–181	artedi	8	109–165
zenithicus	7	92–150	nipigon [2]	2	109–145
reighardi [1]	5	115–142	Coregonus clupeaformis	8	208–264
nigripinnis	8	132–194	Prosopium quadrilaterale	8	87–117
kiyi	7	116–167			

[1] Lake Michigan specimens. [2] Lake Nipigon specimens.

It appears that in Leucichthys *hoyi* and *zenithicus* have, on the average, the fewest cæca, while *johannæ* has the most. The ranges of the former overlap that of the latter, and more counts probably will show that overlapping occurs to a greater extent than appears in the table. Coregonus has, on the average, more cæca than either Leucichthys or Prosopium and thereby is differentiated sharply from the latter, which has fewer cæca than most Leucichthys. It is possible that this character is influenced by nutrition.

Head Form

The head in all forms presents four surfaces—a dorsal, a ventral, and two lateral. The dorsal surface is bounded approximately by a line running from the articulation of the maxillary caudad along the dorsal edge of the orbit, and the ventral by a line running caudad along the inner edge of the dentary.

In Leucichthys the dorsal surface has the form of a trapezoid with two equal sides, due to the shape and position of the premaxillaries, and is more or less convex from side to side, the degree of convexity becoming greatest in the region of the occiput. A faint carina, which becomes more conspicuous on drying, runs through its length. The lateral surfaces are nearly flat and converge distinctly in a downward direction. In shape they are roughly triangular, depending again on the shape and position of the premaxillaries. In *alpenæ* the apex is rather rounded, in *reighardi* truncated, and in the rest rather acute or obtuse as the angle made by the premaxillaries with the body axis becomes greater than 45°. The ventral surface, like the dorsal, is convex and corresponds to it in shape.

The depth and width of the head is greatest in *artedi* and *nigripinnis*. The depth is least in *reighardi* and *zenithicus*. The proportion of the head length to that of the whole fish, expressed by L/H, is but slightly different for the forms of this group and therefore has little systematic value. (See Table 8.) Its significance is reduced further by the fact that it changes with the growth of the individual. The races of *artedi*, however, tend to have proportionally the shortest heads among the forms of Leucichthys.

The relative head length varies within the species, often to a conspicuous extent. Making allowance for difference in size between the groups of individuals compared, it seems that in *johannæ* and *alpenæ* the head is somewhat larger in Huron; in

zenithicus it seems smaller in Michigan and Huron and larger in Nipigon than in Superior; in *reighardi* it is longer in Nipigon and Superior and shorter in Ontario than in Michigan; in *nigripinnis* it is larger in Nipigon, Superior, and Huron than in Michigan; in *kiyi* it appears to be smaller in Ontario than in the other lakes; in *hoyi* it appears to be smaller in Michigan than in the other lakes.

Within the species group *artedi* the races differ in the average value of L/H. Thus, the *manitoulinus* race has a much larger head, relatively, than the *artedi* race of Lake Huron, and the *albus* races of Superior and Erie tend to have a relatively longer head than the *artedi* races associated with them.

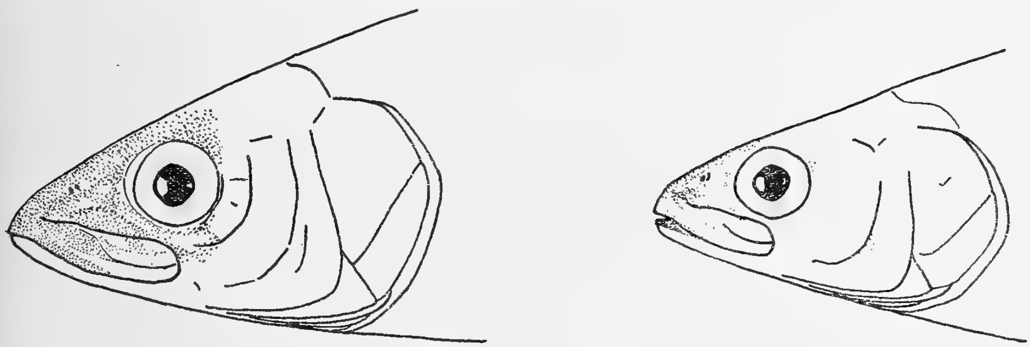

FIG. 11.—Comparison of the heads of *Leucichthys zenithicus* (A) and *L. reighardi* (B) of Lake Michigan

The shape of the head in Coregonus is approximately as in Leucichthys, but the dorsal surface is triangular, due to the shortness of the premaxillaries, and is strikingly convex in the region of the nostrils and occiput. A carina, which is heaviest over its

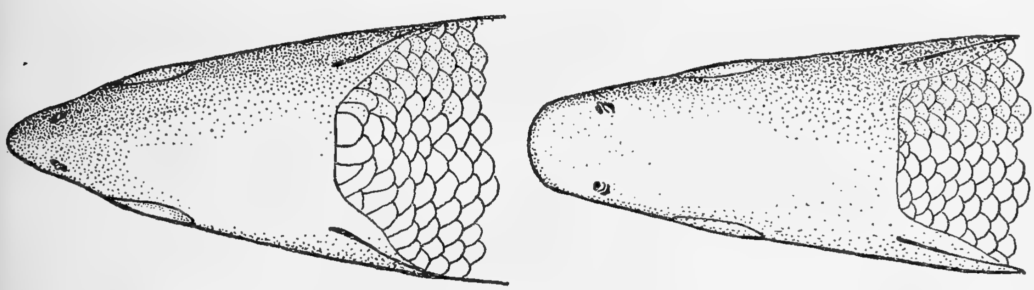

FIG. 12.—Comparison of the dorsal view of the head in Prosopium (A) and Coregonus (B)

anterior extent, bisects the triangle. The lateral surfaces also are triangular in shape, obtuse, or acute at the apex, as the angle made by the premaxillaries with the body axis becomes greater than 90°. The ventral surface is like the doral in shape but is only slightly convex from side to side.

The head in Prosopium is quite different from that in the other two genera. The dorsal surface is acutely triangular, owing to the compression of the entire preorbital region, and is not strongly convex from side to side except in the occipital region. A short but heavy medium keel runs forward from a point approximately above the caudal margin of the eye to its center. A fainter keel originates on each side of it.

slightly farther craniad, and extends to the nares. The lateral surfaces are roughly ovoid in shape. They are nearly flat to a line on a level with the superior edge of the maxillaries and from thence converge sharply in a downward direction, the more sharply as the snout is approached. The ventral surface also is acutely triangular in form but is strongly convex from side to side.

It appears from Table 8 that the head is smallest in proportion to the total body length in this genus. There seems to be variation in this character; the race of Michigan seems to have a proportionally smaller head than those of Superior and Huron.

Brain Box

An examination of the bones of the skull shows the prefrontal bone to extend almost completely over the orbit in Leucichthys and the carina of the frontals to extend to the frontal-parietal suture. In Prosopium the prefrontal is but little developed and does not extend much beyond the anterior edge of the pupil; the cranial carina does not extend to the frontal-parietal suture. In Coregonus the development of these structures is about as in Leucichthys.

Premaxillaries

The shape and position of the premaxillaries serve to separate the three generic groups and to aid in the separation of *reighardi* and *zenithicus* from the other species of Leucichthys. In Leucichthys the premaxillaries are longer than wide and make an angle not in excess of 90° with the horizontal axis of the body behind them. This angle usually is between 60° and 75° for typical *reighardi* and *zenithicus* and 45° and 60° for the others, including the *dymondi* form of *reighardi*. In Coregonus and Prosopium they are wider than long and the angle is always in excess of 90°. The angle may vary within the species; the premaxillaries are less perpendicular in the *dymondi* race of *reighardi* than in the typical one.

Snout

The shape of the snout depends, of course, upon its length and on the position of the premaxillaries. It is more blunt or more pointed, according as the premaxillaries are more vertical or more horizontal. The relative length of the snout, as compared with the length of the head, is variable and is not distinctive for any species. It is longest, on the average, in *zenithicus*.

The usual length may vary within a species. *Johannæ* has a longer snout in Huron than in Michigan; *zenithicus* has a somewhat longer snout in Nipigon than in Superior and a somewhat shorter one in Michigan and possibly Huron; the *reighardi* of Nipigon and of northern Lake Michigan has a somewhat longer snout than the typical form, and the Superior form has a somewhat shorter one; the *cyanopterus* subspecies of *nigripinnis* has a relatively longer snout than the other races; *kiyi* in Superior has a somewhat shorter snout than in the other lakes.

Maxillary

The shape and size of the maxillary and the supplementary maxillary (jugal) are more or less distinct for the three groups. In Leucichthys both of these bones are elongated more than in the other two groups. While in Leucichthys the max-

illary, in proportion to the head, is relatively shortest in *artedi* and *reighardi*, the figures are not exclusive. Coregonus has a shorter maxillary than most forms of Leucichthys, but the range overlaps slightly. Prosopium has relatively the shortest maxillary of all, and its figures overlap but little those of Coregonus. The usual value for H/M in typical *artedi* and the *albus* form is 2.7 to 2.9; in typical *reighardi*, 2.6 to 2.8; in the other forms of Leucichthys, 2.3 to 2.6; in Coregonus, 3.1 to 3.4; and in Prosopium, 4.0 to 4.2.

The maxillary length also varies within the species, so that in *zenithicus* it is somewhat shorter in Michigan and Huron; in *reighardi* it is longer in Superior and Nipigon than in Michigan and somewhat shorter in Ontario; in *hoyi* it is longer in Superior and Nipigon. In the species of one lake it also varies. Thus, *reighardi* of northern Lake Michigan has, on the average, a proportionally longer maxillary than that of the south, and the *manitoulinus* race of *artedi* has a much longer maxillary than the typical race.

Mandible

In Leucichthys the lower jaw is approximately equal to the upper; in the other genera it is always distinctly shorter. In the case of *reighardi* and *zenithicus* it is usually (in *artedi* often) somewhat shorter than the upper; in *alpenæ* and *kiyi* it is usually longer than the upper; in *hoyi* it is seldom shorter; in the others it is variable, though most often about equal. It also varies in position within the species, as evidenced by the fact that the forms of *zenithicus* in Michigan and Huron more often have the mandible included; the *dymondi* race of *reighardi* often has the mandible not so conspicuously included; the *cyanopterus* form of *nigripinnis* has the lower jaw shorter than the upper more frequently than the other *nigripinnis* races; and the deep-water *hoyi* of Huron and the *hoyi* of Nipigon and Ontario seem to have longer jaws than their relatives elsewhere.

Within the group Leucichthys there is nothing distinctive about its shape, degree of development, or relative length compared with that of the head. The degree of bony development, however, is most pronounced in *alpenæ* and probably least in *reighardi*. In Leucichthys the value obtained by dividing the mandible into the head never is more than 2.3 and may be as low as 1.7. In Coregonus the value usually is 2.4 to 2.7; in Prosopium it is 2.7 to 3.1.

Eye

The size of the eye varies with the age of the individual and consequently is of ready systematic value only in forms of comparable size or state of development. The values obtained by dividing the eyeball into the head are given in Table 9, first for the adults of the larger forms and then, so far as possible, for their young, for comparison with the former and with the smaller species of the group. As is usual in fishes, the eye appears to be relatively larger in the young than in the adult and the values are not very different for any of the species.

The eye size also varies within the species. The *alpenæ* of Huron seems to have a proportionally smaller eye than that of Michigan; *zenithicus* of Nipigon seems to have a somewhat larger eye than that of other lakes; the *reighardi* of Ontario and Nipigon seem to have a smaller eye than those from other lakes; *nigripinnis* in Nipigon

and Huron have relatively larger eyes, and those in Superior have relatively smaller eyes than the form in Michigan; in *hoyi* the eye is proportionally larger in the Superior and Nipigon forms and smaller in the Ontario race; in *artedi* the *manitoulinus* form has a relatively larger eye than the other subspecies of *artedi*.

Teeth

Vestigial teeth have been found in the forms of all species except *quadrilaterale*. They are present more or less regularly on the premaxillaries, the palatines, the mandible, and on the tongue, and are least in evidence in the larger individuals of each species. Those on the tongue appear to be retained longest. The absence of teeth then serves to separate Prosopium from the other genera.

Branchiostegal Membrane and Rays

The outline of this membrane and the number of its rays have no taxonomic value in this group, except that Prosopium differs from the other two groups in both of these respects. In the latter the membrane is saber-shaped and usually contains 8 to 10 rays. In Prosopium it is trapezoidal in outline, and there are only 7 or 8 rays.

Gill Rakers

The number of gill rakers is of great systematic importance. Leucichthys has the most and longest rakers and Prosopium the fewest and shortest. The range of the latter overlaps that of none of the other species; that of Coregonus overlaps but rarely the range of any species other than *johannæ*.

Leucichthys may be divided into three groups: (1) Gill rakers on the first arch commonly less than 33 (*johannæ*); (2) usually more than 32 and usually less than 44 (*alpenæ, zenithicus, reighardi, and kiyi* (except in Ontario); (3) usually more than 43 (*nigripinnis* except in Superior, *artedi* and *nipigon*). The range of *hoyi* and Ontario *kiyi* is about intermediate between 2 and 3. Superior *nigripinnis* falls about in Group 2. As has been indicated above, there may be some variation in the number of gill rakers on the first branchial arch within a species. The *alpenæ* of Huron have somewhat fewer gill rakers than those of Michigan; they are somewhat fewer in the *zenithicus* of Nipigon and Huron than in those of other lakes; they are somewhat fewer in the *reighardi* of Nipigon; in the *nigripinnis* of Nipigon they are more numerous, and they are fewer in the Superior form; they are more numerous in the *kiyi* of Ontario; they are more numerous in the *hoyi* of Nipigon and Ontario.

Within the species of a lake no striking variation tendencies have been noted in any of the races. It is noticeable, however, that in the case of *alpenæ* and *zenithicus* small fish have somewhat fewer gill rakers, due, no doubt, to the imperfect development of those on the ends of the arches.

Nares

The structure of the nares is a distinctive feature in Prosopium. In Leucichthys and Coregonus the anterior opening is through a short tube obliquely truncated toward the front, and a rather broad membranous flap is present at the anterior end of the posterior opening. In Prosopium this flap is wanting. (See fig. 27.)

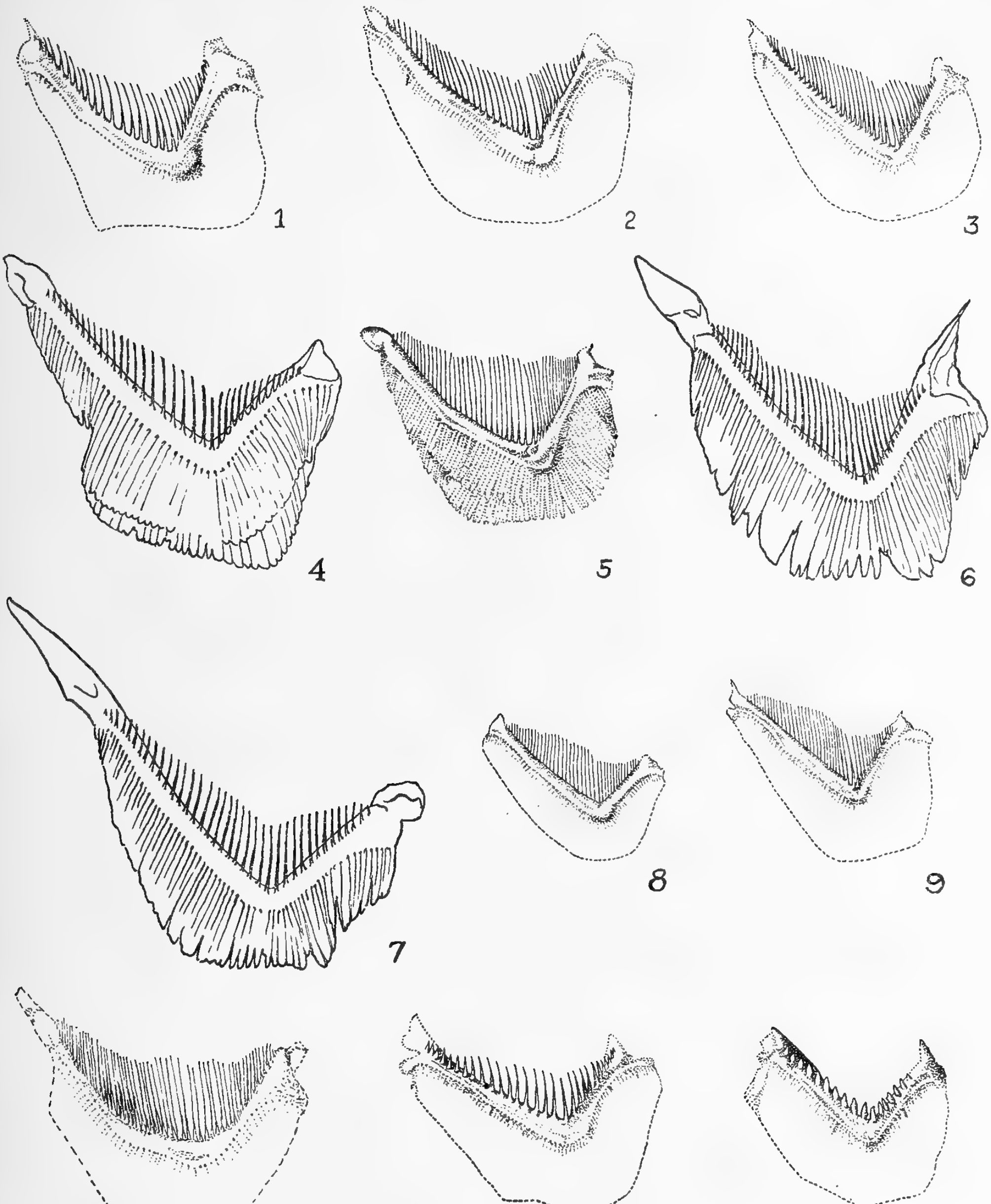

FIG. 13.—Left branchial arch of 12 forms of Coregonidæ found in the Great Lakes (Nos. 4 and 7 are drawn from the type specimens from Lake Michigan; No. 6 from a Lake Superior individual; the rest are from Lake Huron specimens.) 1. *Leucichthys johannæ.* 2. *L. alpenæ.* 3. *L. zenithicus.* 4. *L. reighardi* (type). 5. *L. nigripinnis.* 6. *L. nigripinnis cyanopterus.* 7. *L. kiyi* (type). 8. *L. hoyi.* 9. *L. artedi.* 10. *L. nipigon.* 11. *Coregonus clupeaformis.* 12. *Prosopium quadrilaterale.*

DISCUSSION OF VARIABILITY

Interspecific Variations

From the foregoing analyses it is evident that while there are adequate characters to distinguish between the three genera, such as shape of the head and premaxillaries, size of maxillary and mandible, teeth, branchiostegal membrane, number and length of gill rakers, structure of nares, pearl organs, etc., there are comparatively few characters that can be used to separate the species within a group. It has been shown that the number of rakers on the first branchial arch is of greatest value in distinguishing the specific forms. Separated by this character, most of the coregonid forms fall into four groups: (1) Rakers usually less than 20 (*quadrilaterale*); (2) rakers usually more than 20 and less than 33 (*clupeaformis* and *iohannæ*); (3) rakers usually more than 32 and less than 44 (*alpenæ, zenithicus, reighardi, kiyi,* and *nigripinnis* of Superior); (4) rakers usually over 43 (*nigripinnis* except Superior, *artedi* and *nipigon.*)

Both *quadrilaterale* and *clupeaformis* are distinct from the other forms in the Great Lakes and from each other, and each is the sole representative of a genus. It is unnecessary, therefore, to consider them in the subsequent discussion.

There remain for consideration the species of Leucichthys, which have hardly any other character than gill rakers by which the species, wherever they may occur, may be separated. Within a lake a few other characters may be of use to distinguish one or two species from the rest (see analyses on pp. 335 to 339), but even these are not very constant, and each taken alone certainly could not be relied upon. The few characters that are fairly constant for each species are repeated below:

1. *Body contour.*—The form of the body is, in general, fairly constant. In *alpenæ, zenithicus, reighardi, hoyi, artedi,* and *nipigon* the body outline, as seen from the side, is generally elliptical; in *johannæ, nigripinnis,* and *kiyi* it is more or less ovate as a rule.

2. *Length of the lower jaw.*—The mandible in *alpenæ* usually projects beyond the upper jaw, while in *zenithicus* and *reighardi* it is generally included within the upper. The other species (except *kiyi* and *artedi*) that normally have equal jaws occasionally may have the lower jaw longer or shorter than the upper. *Artedi* most often has the lower jaw shorter than the upper, while in *kiyi* it is usually a little longer.

3. *Length of the maxillary.*—For *artedi* (except the form *manitoulinus*) the maxillary usually is contained more than 2.6 times in the head length; for the rest (excepting typical *reighardi,* which is intermediate) it usually is contained less than 2.7 times.

4. *Pigmentation of the maxillary.*—This character has more or less systematic value. In *johannæ* and *alpenæ* the maxillary usually is immaculate; in all the rest it most often is more or less pigmented.

The conclusion is unavoidable that those characters that are of greatest importance in the taxonomy of other groups of fishes, such as body proportions, number of scales, fin rays, teeth, etc., are not of prime taxonomic value for the Coregonidæ.

Intraspecific Variations

Analysis of the Great Lakes coregonids shows, in each of the 11 species, a wide range of variation in all the characters that are of taxonomic importance, although

in most of the species this variation is possibly no greater than would be found in other unrelated species if the same number of individuals of these were studied in the same way. This variation is exhibited by individuals presumably intimately related—that is, by individuals of the same school in one locality. In many species it has been found that geographically separated races have developed peculiar characters even within a lake, and it is probable, furthermore, that different schools in one locality would show peculiarities. To cite the most conspicuous examples of differentiation where a species has been segregated definitely, geographically, we have the *dymondi* subspecies of *reighardi* in Nipigon and Superior, the *cyanopterus*, *regalis*, and *prognathus* subspecies of *nigripinnis* in Superior, Nipigon, and Ontario, respectively, and the *orientalis* subspecies of *kiyi* in Ontario. Within a lake we have the conspicuously differentiated forms of *artedi*—*manitoulinus* in Huron and *albus* in Erie and Superior and the unnamed deep-water variant of *hoyi* in Huron.

These various forms probably have arisen through isolation and to some degree may be the result of different environmental conditions operating in each generation. It is not clear, however, what environmental factors might operate to develop the various forms that occur in separated lakes. There seems to be no definite direction of variation expressed by the forms in any lake. Thus, while *nigripinnis* in Superior has fewer gill rakers than any of the known races in other lakes, *zenithicus* in that lake seems to have a few more than its relatives elsewhere. Similarly, though *hoyi* and *kiyi* in Lake Ontario have more gill rakers, it is not true of other coregonids in the lake; and in Nipigon *hoyi* seems to have somewhat more lateral line scales than the *hoyi* elsewhere, while all the other forms of Leucichthys seem to have fewer than their relatives in other lakes.

In the case of the varieties of *artedi* there seems to be some clue as to the causes operating to produce certain characteristics of development, but until a study has been made of the forms of *artedi* known to occur in the inland lakes tributary to the Great Lakes any statement regarding the manner in which environment influences the direction of variation is purely hypothetical. We do know, however, that the forms of *albus* and *manitoulinus* both exhibit the same sort of variations—both have deep, abbreviated bodies with relatively longer paired fins and few lateral-line scales. They are not alike, however, in certain other peculiarities, such as the relatively large head and eye and the dark color of the latter. These varieties always occur in the warmest waters of the territory available for occupation. Lake Erie, which is the shallowest and most southerly of the Great Lakes, presumably is the warmest; and it has been shown in Table 13 that Black Bay, in Lake Superior, is much warmer than the open lake. The same probably is true of Cutler Bay, where *manitoulinus* occurs.

It would be expected that, if temperature had a part in this variation, an opposite type of development would result where temperature conditions were reversed, and this appears to be true. The habitat of the Lake Superior herring is almost certainly the coldest in the Great Lakes occupied by the species throughout the year. The *artedi* of the lake are the slenderest, most elongate forms, and they have the most lateral-line scales, though the paired fins are not conspicuously different from those of Michigan and Huron specimens. It is noteworthy, also, that the *clupeaformis* of Lake Erie and Black Bay of Lake Superior also are known to be

deeper bodied and fewer scaled than their relatives of colder waters. (Nothing is known about the characteristics of the bay races of whitefish in Lake Huron.)

The *artedi* of Nipigon are nearest to the *albus* type, even though Lake Nipigon lies in the highest latitude of the chain; but Lake Nipigon also is much shallower than any of the lakes except Erie, and its annual heat budget is relatively high (Clemens, 1923).

It should be repeated that facts do not warrant the assignment of temperature as a direct factor in occasioning the variations discussed. The cases cited may be coincidences or temperature may act indirectly in numerous ways. The segregation of these variants presumably is a result of physiological differences, differences that have enabled certain individuals to meet the conditions arising from increased warmth or, in the case of the deep-water variant of *hoyi* in Huron, from increased depth. The segregated variants thus are subjected to unlike physical conditions. They differ in certain structural characters. If we assume that the structural differences result from isolation, they may be, in part, the direct or indirect effect of environment (somatic) and in part the result of germinal changes.

Somatic variations might be the direct effect of the activities of the fish in its relation to the degree of mass movement of the water, the abundance and character of food, or of other factors. These should affect the form and proportions of the body through the degree of induced development of muscles or fat. Differences of this sort are well known between individuals of certain species of fresh-water fish taken from different environments, as in the case of the yellow perch. Such somatic variations may be "adaptive," as in the case of alteration of form or proportions due to the degree of development of body muscles. It is also conceivable that differences in physical conditions affect directly the early-growth stages of fish in different environments in such a way as to give rise to somatic variations that are nonadaptive, indifferent, or even harmful. Such variation may appear in "passive" structures such as the skeleton (Jordan, 1892). The monstrosities that often arise from ova developed in hatcheries probably are, in part, an extreme instance of this type of "variation," as are the monsters produced under experimental conditions.

At the same time isolation presumably is accompanied by germinal changes that become manifest in heritable somatic alterations. As in the case of mutations, the adaptiveness of these is wholly contingent. They may or may not prove to be useful. It is possible that the variation in number and form of the gill rakers is of this type. A detailed study of the food of the Lake Huron forms described in this paper indicates that within the genus Leucichthys the relation between the number and form of the gill rakers and the character of the food is very loose. All the deep-water forms of the genus have long, slender rakers, but these differ in number and length in such a way as to be characteristic of species and varieties and thus afford one of the most valuable diagnostic characters. Yet there appears to be very little difference in the food of these forms, which consists chiefly of the schizopod crustacean *Mysis relicta*. Living with the deep-water coregonids is the lawyer, *Lota maculosa*, virtually devoid of gill rakers but often found with its stomach filled with Mysis. The little knowledge that we possess thus suggests that the mean differences in gill rakers characteristic of the coregonid forms are of germinal origin and not primarily of individually adaptive nature. In that case such relation as they now bear to the

size of the customary food organisms is contingent and secondary and the gill-raker characters have the greater value in taxonomy. The differences in form and position of the bones of the upper and lower jaws, as well as other characters exhibited by the different forms, may ultimately prove to belong in the same category

Experimental study of the effect of environmental factors on fishes in their various stages, together with breeding experiments, are, of course, essential to a full understanding of the characters shown by the coregonid forms. The production, by artificial rearing, of very abnormal characteristics in the whitefish indicates that this field may be very fruitful. Meantime, more critical analysis of the accumulated data on variation may throw light on these problems.

The only conclusion that can be drawn safely from a consideration of the variations in these forms is that only certain characters are modifiable by environmental conditions or tend to vary, and that these characters are virtually the same for all the forms. Thus, the variants of all species may differ from the typical forms in respect to head length, number of scales in the lateral line, length of pectorals, number of gill rakers, etc. Furthermore, so many characters are variable that the varieties may be more strikingly differentiated from their nearest relatives than are the species within a group from one another.

SPECIATION IN THE GREAT LAKES COREGONIDS

ORIGIN OF THE COREGONIDS IN THE BASIN

In this paper I have presented evidence to show that 11 distinct species and 7 possible subspecies of the family Coregonidæ are found in the Great Lakes chain.

There are 9 species included in the genus Leucichthys and 1 each in the genera Coregonus and Prosopium. Lake Michigan has 10 of the 11 species, Lake Huron 9, Lakes Superior and Nipigon 8 each, Lake Ontario 7 (though 1 now seems to be extinct), and Lake Erie 2. The distribution of the various species in each lake is shown in Table 5. In general there is little difficulty in correlating the relationships of the various species in the different lakes, but in a few cases the individuals of a species have varied so far, structurally and even physiologically, from the typical form as to appear to merit designation as a distinct species. There is no doubt about the relationships within the species *artedi* (the most variable of all) nor within the species *johannæ*, *alpenæ*, *zenithicus*, *kiyi*, *hoyi*, *clupeaformis*, or *quadrilaterale*. In the case of *reighardi* it might be questioned whether the *dymondi* form of Lakes Nipigon and Superior actually should be included within that species group, and in the case of *nigripinnis* whether the *cyanopterus* of Lake Superior and the *prognathus* of Lake Ontario were grouped properly within *nigripinnis*. The case of the *dymondi* and *cyanopterus* races seems the more confused, as, in addition to marked structural differences (though the habitat selection is about the same), the time of spawning is very different. In this connection it may be pointed out that time of spawning may vary two weeks from year to year for any school of any coregonid, and the time of spawning of races of many species (namely, *clupeaformis* within Lake Michigan, *zenithicus* of Lake Huron, *kiyi* of Lake Ontario, et al., all of them of virtually certain identification) may be a month or two earlier or later than for related races elsewhere in the basin. It is even reported that within recorded time certain species have changed

their time of spawning by a period as great or greater. Inasmuch, then, as spawning time is so variable, the deviation in this particular of the *reighardi* and *nigripinnis* forms loses significance as a specific character. In spite of marked changes in a few systematic characters, the varieties still closely resemble the typical members of their species group; in fact, the resemblance is far closer than that between the whitefish artificially reared in the New York Aquarium and their parents. In the case of *reighardi*, individuals in northern Lake Michigan even show a tendency to vary from the typical form (which occurs in the southern part of that lake) in precisely the same direction that has produced the *dymondi* type.

The systematic scheme here outlined presupposes the presence of 10 distinct species in the Great Basin before the close of the glacial period. The facts of the geological history of the lakes do not contradict the assumption. Two species of coregonids, *artedi* and *clupeaformis*, are distributed in all six of the Great Lakes. Lake Erie is so shallow and warm over most of its extent that probably it is unsuited for any but the most adaptable coregonids; in fact, the bulk of its population is made up of species that thrive best in the bays of other lakes. Three more, *nigripinnis*, *hoyi*, and *quadrilaterale*, occur in each of the other five lakes; *reighardi* and *kiyi* are found in four of the lakes, *johannæ* and *alpenæ* occur in only two and *nipigon* in only one.

Most of the facts of the distribution of the species can be explained by assuming the presence in the basin of an original stock of 10 coregonids. Only 2 of the 10 survived in all the lakes. None of the rest survived in the warmest lake, but three species found suitable conditions in the other five lakes. One (*reighardi*) survived in all the lakes but Huron, and one (*kiyi*) survived in all but Nipigon. Why their range was thus limited is not clear from any known geological facts. One (*zenithicus*) is absent from Lake Ontario; it may have been unable to return after the late marine inundation of old Admiralty Lake. Two (*johannæ* and *alpenæ*) occur only in Lakes Huron and Michigan; they may have originated in one or other of the lakes subsequent to the Lake Algonquin stage, as these lakes are rather intimately connected, or they simply may have perished in the other lakes from competition or from failure to find suitable conditions.

The restriction of *nipigon* to Lake Nipigon (though it is known to occur also in Lake Winnipeg) seems to support the view that Lake Agassiz was not contemporaneous with Lake Algonquin, which joined intimately Nipigon with Superior and the other lakes but came later. In that case the elevation of the basin of Lake Nipigon with the resultant falls that now prevent exchange between the fish faunas of the two lakes has operated to prevent the spread of *nipigon* into the other lakes.

It seems, thus, that the Great Lakes coregonids were differentiated specifically before the Great Lakes attained their present form. The present distribution of the species, considering Lake Erie to be unfit for most coregonids, can be explained by assuming the extinction of three forms, one in each of the three lakes, by the survival of two forms only in two of the lakes or by their late origin in one or the other of the lakes, and by the assumption that Lake Agassiz came later than the Algonquin stage of the Great Lakes. As we know that the last period of glaciation fell within relatively recent time, geologically speaking, it is likely that many of the present racial distinctions originated during the 20,000 years that geologists estimate have elapsed since the formation of something like the present lakes.

PHYSIOLOGICAL BARRIERS BETWEEN THE SPECIES

It does not appear to be profitable, in the present state of our knowledge of the coregonids of other waters, to speculate further on the origin and precise relationships of the forms in the Great Lakes; but two points are clear—first, that from whatever source the species may have originated, certain factors are operating now to keep them distinct; and second, as I have already indicated, tendencies that may result in the formation of new species are manifesting themselves in at least some of the species already formed.

The factors that keep the species apart apparently are physiological differences between the individuals of different species, differences that result (*a*) in the selection of different habitats and (*b*) in breeding taking place at different seasons, at different depths, and on different bottom.

Segregation Through Different Habitat Selection

The physical conditions in the lakes vary, and the adaptability of the species also is different, so that it is not possible to generalize too strictly about the habitat selection of any species in the basin. In some lakes species that regularly inhabit shallow water elsewhere may be driven, by competition on the shoals or by absence of shoals, to find a living in deeper water; and, being adaptable, they may thrive there (Lake Ontario). In other cases species that regularly inhabit deep water have been known to occur abundantly in shallow water only (Lake Nipigon); but, in general, in any lake there are certain groups of species that are found in shallower water than others. In general, *artedi*, *clupeaformis*, and *quadrilaterale* are shoal-loving forms; *alpenæ*, *zenithicus*, *reighardi*, and *hoyi* also like comparatively shallow water; but *johannæ*, *nigripinnis*, and *kiyi* are found chiefly in the deeper waters.

The bathymetric distribution of the species or groups of species is zonal. Each occupies a rather broad zone defined by the depth of water at its margins. At the center of the zone each has its greatest density of population, and this density diminishes toward the margin of the zone. Only a few stragglers are found beyond their zones, except during the breeding migration. The zones overlap at their margins, so that the different forms are intermingled there in relatively small numbers.

There are no data to indicate why these zones have been selected by the various species or groups of species. Nothing is known about their reactions to the various physical and chemical factors of their environment. Possibly the selection is influenced by the character of the bottom. Throughout the area inhabited by the shoal group, the hydrographic map shows rock, gravel, and sand, and in the deeper parts of the lakes clay and mud. While each species may range over all these types of bottom within its zone, of course it is not only possible but probable that there are differences in the character of the areas designated on the chart as mud, clay, etc., and that these differences influence, indirectly, the distribution of the fish. Certainly all the forms except *artedi* (which is a plankton feeder and therefore normally takes its food above the bottom), so far as known, are confined to a bottom stratum of water of a thickness of not more than 5 feet. In this stratum they find their food, which consists (in all the forms) chiefly of various species of Crustacea and Mollusca. The character of the food available probably is determined directly by the character of the bottom, and therefore a knowledge of the food regularly taken by each species would be helpful in defining this factor of the habitat.

Segregation Through Different Breeding Habits

Most of the species are separated from one another by spawning at different seasons or on different grounds. The three shoal forms (*clupeaformis, quadrilaterale,* and *artedi*), wherever they occur in the basin, spawn at approximately the same season—that is, in November and early December—but it is not known that they congregate on the same grounds at the same time. These forms, however, are so far removed from one another that it is not likely that hybridism would occur commonly. What is known of the spawning habits of the other species indicates that within each lake each species has a distinct breeding time or place, or both. To be sure, little is known about this part of the life history of the Nipigon forms, and there are gaps in our knowledge of the breeding habits of some of the forms in the other lakes.

In Lake Michigan *hoyi* is the earliest spawner. It spawns in March at depths of about 20 to 30 fathoms. *Reighardi* spawns in May, probably in shallower water. *Johannæ* spawns in August or September, presumably at depths of 60 fathoms. *Kiyi* is said to spawn in October, also at great depths. *Zenithicus* and *alpenæ* spawn in November, but it is not known that they spawn on the same grounds. Data indicate that the former spawns in deeper water. *Nigripinnis* spawns in January at depths of about 60 fathoms.

In Lake Superior it is not known when or where *hoyi* spawns, but certainly it is not before December. *Nigripinnis* spawns in 60 fathoms in September. *Kiyi, zenithicus,* and *reighardi* all spawn in November, as do *artedi, clupeaformis,* and *quadrilaterale,* but no one knows that any two spawn on the same grounds at the same time.

In Lake Huron the breeding habits of its species are about like those of related forms in Michigan, except that *zenithicus* spawns in late September and early October and *kiyi* may spawn in early November.

In Ontario *reighardi* is known to spawn some time in spring, probably in May. *Kiyi* spawns in August, probably in deep water. *Nigripinnis* is said to have spawned at about 60 fathoms in January. It is not known when *hoyi* spawns, but the season may be as in Lake Michigan.

The data just reviewed indicate that whatever rôle physiological differences between the various species may have played in species formation they now are an important factor in keeping the species distinct. Thus, habitat preferences separate the species or groups of species into different zones, and differences in breeding behavior cause each species to deposit its eggs at a different time or in a different place.

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SPECIES OF COREGONIDÆ IN THE GREAT LAKES

ANALYSES OF THE SPECIES

LAKE NIPIGON

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of the adjacent rows; gill rakers more than 23, relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; lower jaw contained not more than 2.3 times in the head; gill rakers relatively long and usually more than 31; maxillary seldom contained more than 3 times in the head---Genus Leucichthys

a. Gill rakers usually less than 40.

1. Gill rakers usually more than 36; snout usually contained less than 3.5 times in the head and usually less than 2.2 times in the head depth; the head depth usually contained more than 6.2 times in the head; mandible usually shorter than the upper jaw---*zenithicus*

2. Gill rakers usually not more than 36; snout usually contained not less than 3.5 times in the head and usually more than 2.1 times in the head depth; the head depth usually contained not more than 6.2 times in the head; mandible usually shorter than the upper jaw---*reighardi dymondi*

aa. Gill rakers usually more than 40 and less than 54.

b. Paired fins conspicuously black; body shape in side view ovate; fish commonly attaining a length of 300 millimeters (12¾ inches) or more.

3. Gill rakers usually 48–51; pectorals usually contained 1.4–1.6 times in the pectoral-ventral distance; ventrals usually contained 1.2–1.5 times in the ventral-anal distance---*nigripinnis regalis*

bb. Paired fins pale, or at least not conspicuously pigmented; body shape in side view elliptical; fish not known commonly to attain a greater length than 250 millimeters (8 inches).

4. Gill rakers usually not more than 46; maxillary usually contained less than 2.6 times in the head; mandible usually superior and hooked---*hoyi*

5. Gill rakers usually more than 46; maxillary usually contained more than 2.6 times in the head; lower jaw usually equal to or shorter than the upper, never hooked---*artedi*

aaa. Gill rakers seldom less than 54.

6. Fish attaining a length of more than 300 millimeters (12¾ inches); fins moderately pigmented---*nipigon*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained not less than 3 times in the head, but less than 3.8; lower jaw usually contained 2.4–2.7 times in the head; gill rakers less than 32 and more than 20 .... *Coregonus clupeaformis*

AA. A single flap between the openings of a nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of adjacent rows; gill rakers less than 20, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; mandible contained not less than 2.7 times in the head; no vestigial teeth; body subterete .... *Prosopium quadrilaterale*

LAKE SUPERIOR

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of the adjacent rows; gill rakers more than 23, relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; mandible contained not more than 2.3 times in head; gill rakers relatively long and usually numerous; maxillary seldom contained more than 3.1 times in the head .... Genus Leucichthys

a. Lower jaw usually longer than the upper and more or less hooked; fish seldom longer than than 200 millimeter (7⅞ inches); body usually conspicuously bloated.

1. Body shape in side view ovate; gill rakers usually less than 41; lateral-line scales usually more than 75; pectorals usually contained less than 1.6 times in the pectoral-ventral distance .... *kiyi*

2. Body shape in side view elliptical; gill rakers usually more than 40; lateral-line scales usually less than 76; pectorals usually contained more than 1.5 times in the pectoral-ventral distance .... *hoyi*

aa. Lower jaw usually equal to or shorter than the upper, seldom conspicuously longer and hooked; fish attaining length of 300 millimeters or more (12¾ inches).

b. Gill rakers usually more than 43.

3. Lateral-line scales seldom less than 80; pectorals seldom contained less than 2 times in the pectoral-ventral distance; ventrals seldom contained less than 1.6 times in the ventral-anal distance; head in adults usually contained 4.3–4.6 times in the total length; maxillary usually contained 2.7–3 times in the head; body subterete .... *artedi artedi*

4. All figures given above tend to be less and the body deeper and more compressed in .... *artedi albus*

bb. Gill rakers usually not more than 43.

c. Body shape ovate in side view; fish spawning in September.

5. Sum of the head depth and the anal base divided by the sum of the maxillary and the snout usually 1.65–1.75; body usually deeper than under *cc;* mandible tip usually conspicuously pigmented .... *nigripinnis cyanopterus*

cc. Body shape elliptical in side view; fish spawning in November or later; lower jaw usually shorter than the upper; mandible usually immaculate or faintly pigmented.

6. Gill rakers usually less than 39; snout usually contained 3.6–3.9 times in the head; eye in adults usually contained 3.9–4.2 times in the head; length of the pectoral fin usually contained 1.8–2 times in the pectoral-ventral distance ... *reighardi dymondi*

7. Gill rakers usually not less than 39; snout usually contained 3.3–3.6 times in the head; eye in adults usually contained 4.2–4.6 times in the head; the sum of the head depth and anal base divided by the sum of the maxillary and snout usually 1.45–1.55 .... *zenithicus*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained more than 3.1 but less than 3.8 times in the head length; mandible usually contained 2.4–2.7 times in the head; gill rakers 24–31; ventrals usually contained less than 1.9 times in the ventral-anal distance .... *Coregonus clupeaformis*

AA. A single flap between the openings of the nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of adjacent rows; gill rakers 15–20, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; mandible contained not less than 2.7 times in the head; no vestigial teeth; body subterete; ventrals usually contained not less than 1.9 times in the ventral-anal distance_____*Prosopium quadrilaterale*

LAKE MICHIGAN

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of those of the adjacent rows; gill rakers more than 23 relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; lower jaw contained not more than 2.3 times in the head; gill rakers relatively long and usually numerous; maxillary seldom contained more than 3.1 times in the head__________Genus Leucichthys

a. Gill rakers usually less than 33.

1. Maxillaries and premaxillaries usually unpigmented; mandible usually equal to the upper jaw; pectorals usually contained 1.6–1.8 times in the pectoral-ventral distance____*johannæ*

aa. Gill rakers usually more than 32 and less than 45 (except *hoyi*, which may often have 45).

b. Lower jaw shorter than the upper.

2. Gill rakers usually 38–42; pectorals usually contained 2–2.2 times in the pectoral-ventral distance; mandible usually immaculate, or at least not conspicuously pigmented; snout and maxillary relatively long, usually contained 3.4–3.7 and 2.4–2.6 times in the head____*zenithicus*

3. Gill rakers usually 34–38; pectorals usually contained 2–2.5 times in the pectoral-ventral distance; mandible usually conspicuously pigmented; snout and maxillary relatively short, especially in the southern half of the lake_____________*reighardi*

bb. Lower jaw seldom shorter than the upper, usually longer.

c. Maxillary usually immaculate; mandible well developed; fish commonly attaining size of more than 250 millimeters (about 10 inches).

4. Gill rakers usually 36–43; pectorals usually contained 1.9–2.2 times in the pectoral-ventral distance; body shape in side view usually elliptical_______________*alpenæ*

cc. Maxillary seldom immaculate; mandible usually frail; fish seldom longer than 250 millimeters (about 10 inches).

5. Body shape in side view ovate; pectorals usually contained 1.4–1.7 times in the pectoral-ventral distance; ventrals usually contained 1–1.3 times in the ventral-anal distance; gill rakers usually less than 41; lateral-line scales usually more than 77; fall spawners____*kiyi*

6. Body shape in side view elliptical; pectorals usually contained 1.7–2 times in the pectoral-ventral distance; ventrals usually contained 1.2–1.4 times in the ventral-anal distance; gill rakers usually more than 40; lateral-line scales usually less than 78; spring spawners____*hoyi*

aaa. Gill rakers usually more than 44.

7. Body shape in side view broadly ovate; flesh fat and soft; pectorals usually contained 1.6–1.8 times in the pectoral-ventral distance; ventrals usually contained 1.3–1.5 times in the ventral-anal distance; maxillary usually contained less than 2.7 times in the head; paired fins usually conspicuously pigmented_____________*nigripinnis*

8. Body shape in side view elongately elliptical; flesh firm; pectorals usually contained 1.9–2.2 times in the pectoral-ventral distance; ventrals usually contained 1.6–1.8 times in the ventral-anal distance; maxillary usually contained more than 2.6 times in the head; paired fins not conspicuously pigmented_______________*artedi*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained more than 3.1 but less than 3.8 times in the head; mandible usually contained 2.4–2.7 times in the head; gill rakers 24–31; ventrals usually contained less than 2 times in the ventral-anal distance____*Coregonus clupeaformis*

AA. A single flap between the openings of a nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of adjacent rows; gill rakers 15–19, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; lower jaw contained not less than 2.7 times in the head; no vestigial teeth; body subterete; ventrals usually contained not less than 2 times in the ventral-anal distance------*Prosopium quadrilaterale*

LAKE HURON

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of those of the adjacent rows; gill rakers more than 23, relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; lower jaw contained not more than 2.3 times in the head; gill rakers relatively long and usually numerous; maxillary seldom contained more than 3.1 times in the head----------Genus Leucichthys

a. Gill rakers usually less than 33.

1. Length of the pectoral fin usually 1.5–1.8 times in the pectoral-ventral distance; pectoral rays usually 17 or 18; jaws usually equal; body shape in side view rather ovate; fish spawning in August and September----------------------*johannæ*

aa. Gill rakers 31–45, seldom less than 33 or more than 43.

b. Body outline in side view ovate; pectorals usually contained 1.4–1.7 times in the pectoral-ventral distance; ventrals usually contained 1–1.2 times in the ventral-anal distance.

2. Mandible usually projecting and strongly hooked; maxillary pigmented; fish seldom over 200 millimeters long (7⅞ inches); usually conspicuously bloated; lateral-line scales usually 75–83; gill rakers usually 36–40----------------------------*kiyi*

bb. Body outline in side view elliptical; pectorals usually contained more than 1.7 times in the pectoral-ventral distance; ventrals usually contained more than 1.2 times in the ventral-anal distance.

c. Gill rakers usually 40–43; mandible frail and usually projecting; fish seldom over 200 millimeters long (7⅞ inches); snout short; the head in side view sharply triangular; spring spawners.

3. Maxillary pigmented; fish usually conspicuously bloated----------------------*hoyi*

cc. Gill rakers usually 33–37; mandible well developed, either longer or shorter; snout longer and rounded or truncated, so that the head in side view is not distinctly triangular. Fish attaining adult size of 300 millimeters and more (12¾ inches); spawning in fall; pectorals relatively short.

4. Mandible strong; usually projecting beyond the upper jaw; maxillary usually immaculate; premaxillaries less vertical in position; fish spawning in late November--*alpenæ*

5. Mandible moderately developed and usually shorter than the upper jaw; maxillary usually pigmented; premaxillaries nearly vertical; fish spawning in September–October---*zenithicus*

aaa. Gill rakers usually more than 43.

bbb. Body shape in side view ovate; flesh soft and fat; fish seldom found at depths of less than 35 fathoms.

6. Abdominal fins usually conspicuously black; Pv/P seldom more than 1.8; Av/V usually less than 1.5; H/M usually less than 2.7--------------------*nigripinnis*

bbbb. Body shape in side view elliptical; flesh firmer and with little oil; fish seldom found as deep as 35 fathoms.

7. Abdominal fins not conspicuously black; Pv/P usually more than 1.8; Av/V usually more than 1.5; L/D usually more than 3.9; H/M usually more than 2.8--*artedi artedi*

8. Abdominal fins usually conspicuously black; Pv/P usually less than 1.8; Av/V usually less than 1.5; L/D usually less than 3.9; H/M usually less than 2.8--*artedi manitoulinus*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained more than 3.1 times in the head length, but usually less than 3.8; lower jaw usually contained 2.4–2.7 times in the head; gill rakers 24–31; Av/V usually less than 1.9---*Coregonus clupeaformis*

AA. A single flap between the openings of a nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of the adjacent rows; gill rakers 15–19, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; lower jaw contained not less than 2.7 times in the head; no vestigial teeth; body subterete; Av/V usually more than 1.9 -- *Prosopium quadrilaterale*

LAKE ERIE

A. Premaxillaries longer than wide, oblique in position, never retrorse; lower jaw contained not more than 2.3 times in the head; gill rakers long and never less than 40--- Genus Leucichthys

1. L/D usually more than 3.7; Pv/P usually more than 2; Av/V usually more than 1.7; lateral-line scales usually more than 79----------------------------- *artedi artedi*
2. L/D usually less than 3.7; Pv/P usually less than 2.1; Av/V usually less than 1.8; lateral-line scales usually less than 79------------------------------ *artedi albus*

B. Premaxillaries wider than long, retrorse in position; maxillary usually contained more than 3.1 times in the head; lower jaw usually contained more than 2.3 times in the head; gill rakers always less than 40----------------------------------- *Coregonus clupeaformis*

LAKE ONTARIO (L. NIGRIPINNIS PROGNATHUS EXCEPTED)

A. Two flaps between the openings of a nostril; exposed area of the scales of the lateral line not conspicuously smaller than that of those of the adjacent rows; gill rakers more than 23, relatively long and slender; maxillary usually contained less than 3.8 times in the head; vestigial teeth usually present on the premaxillaries, palatines, mandible, and tongue; body usually laterally compressed.

B. Premaxillaries longer than wide, usually oblique in position, never retrorse; mandible contained not more than 2.3 times in the head; gill rakers relatively long and usually numerous; maxillary seldom contained more than 3.1 times in the head------------- Genus Leucichthys

a. Gill rakers usually less than 41.

1. Mandible included within the upper jaw; body little compressed laterally; pectorals usually contained more than 2.1 times in the pectoral-ventral distance; ventrals usually contained more than 1.4 times in the ventral-anal distance; spring spawners--- *reighardi*

aa. Gill rakers usually more than 40.

b. Body shape in side view usually ovate; fish spawning in summer.

2. Lateral-line scales usually more than 75; adipose usually contained less than 3.8 times in the head; lower jaw usually longer than the upper; ventrals usually contained less than 1.5 times in the ventral-anal distance------------------- *kiyi orientalis*

bb. Body shape in side view usually elliptical; fish spawning in late fall.

3. Gill rakers seldom more than 47; lateral-line scales seldom more than 76; ventrals usually contained less than 1.6 times in the ventral-anal distance; maxillary usually contained less than 2.8 times in the head; mandible usually longer than the upper jaw--- *hoyi*
4. Gill rakers often more than 47; lateral-line scales often more than 76; ventrals usually contained more than 1.5 times in the ventral-anal distance; maxillary usually contained more than 2.7 times in the head; mandible seldom longer than the upper jaw-- *artedi*

BB. Premaxillaries wider than long, retrorse in position; maxillary usually contained not less than 3.1 times in the head, but less than 3.8; lower jaw usually contained 2.4–2.7 times in the head; gill rakers less than 32 and more than 20----------------- *Coregonus clupeaformis*

AA. A single flap between the openings of a nostril; exposed area of the scales of the lateral line conspicuously smaller than that of those of adjacent rows; gill rakers less than 20, the length of the longest not more than 5 per cent of the head; maxillary usually contained more than 3.8 times in the head; premaxillaries wider than long, retrorse in position; mandible contained not less than 2.7 times in the head; no vestigial teeth; body subterete.

Prosopium quadrilaterale

DESCRIPTIONS OF THE COREGONIDÆ IN THE GREAT LAKES

Genus LEUCICHTHYS Dybowski

Argyrosomus Agassiz, 1850, p. 339 (*clupeiformis* of DeKay, not of Mitchill–*artedi*). Not of de la Pylaie.
Leucichthys Dybowski, 1874, p. 390; Dybowski, 1876, p. 18 (*Coregonus omul* Pallas).
Allosomus Jordan, 1878, p. 361 (*Coregonus tullibee* Richardson).
Thrissomimus Gill, in Jordan and Evermann, 1911 (*Coregonus artedi* LeSueur).
Cisco Jordan and Evermann, 1911 (*Argyrosomus nigripinnis* Gill).

Dybowski (1874) proposed the name Leucichthys for *Coregonus omul* Pallas and *Coregonus tugun* Pallas, coregonids with "der Mund vorderständig oder halb oberständig. Die Symphyse des Unterkiefers mit einer höckerartigen Anschwellung." There is nothing in the descriptions of either *omul* or *tugun* to indicate that they differ from our lake herrings, except that he says for *tugun* "Oberkiefer mit einer Reihe schwacher Zähnchen besetzt." It is apparent at once that no fish held to be a *Coregonus* would likely have toothed maxillaries, and reference to the original paper, which Dybowski (1874, p. 383) says was presented for publication to the Siberian division of the Geographic Society in Irkutsk in the winter of 1871, but which did not, in fact, appear in the publications of the society until February, 1876, suggests that Dybowski meant "Unterkiefer" instead of "Oberkiefer." The Russian edition says of *tugun* "mandible provided with a row of faint teeth." Dybowski, in his original paper, rated Leucichthys as a subgenus together with *Coregonus sensu strictiore* under the genus Coregonus. European ichthyologists generally have not recognized Leucichthys as a genus or even as a subgenus.

Jordan and Evermann (1911) substituted the name Leucichthys for the genus Argyrosomus established by Agassiz to include the lake herrings, but which (the authors quote Gill here) was preoccupied, the name having been used in 1835 by de la Pylaie for the "maigre" (*aquila*) of the Mediterranean. Under Leucichthys three subgenera—Allosomus, Thrissomimus, and Cisco—are recognized. The representatives of the subgenus Allosomus I regard as subspecies of certain species in the Thrissomimus group. I find, further, no possibility of distinguishing structurally between the species of the latter group and those of Cisco and therefore do not subdivide the genus Leucichthys.

The Great Lakes representatives of the genus Leucichthys are fish of medium size, seldom larger than 1½ pounds in weight. The premaxillaries are longer than wide and oblique or nearly vertical but never retrorse in position. There are two flaps between the openings of each nostril. The exposed area of the scales of the lateral line is not conspicuously smaller than that of those of the adjacent rows. The gill rakers are relatively long and numerous (*johannæ* excepted). The maxillary usually is contained less than 3 times in the head. The mandible is contained not more than 2.3 times in the head. Vestigial teeth usually are present on the premaxillaries, palatines, mandible, and tongue. The prefrontal bone is elongated and extends almost completely over the orbit. The carina of the frontals extends to the frontal-parietal suture.

The species described in the following pages fall into three ecological groups whose relations are considered in another place. These groups are, in the order in which they are considered in the text, (1) the chubs *johannæ, alpenæ, zenithicus,*

reighardi, and *nigripinnis*, and in some lakes the bloaters (*hoyi*) and the kiyi (*kiyi*), all of which occur in deep water; (2) the lake herring *artedi* and possibly *nipigon*, shallow-water forms feeding chiefly above the bottom; and (3) the whitefishes *clupeaformis* and *quadrilaterale*, shallow-water forms feeding chiefly on the bottom. The natural history of most of these forms is treated in connection with descriptions that follow. The chubs and bloaters, however, are a commercial group, the members of which are handled by the fishermen as a unit, as all are taken in gill nets set in deep water. It is convenient, therefore, to analyze here the data concerning them, obtained chiefly from fishermen's records, and to see what conclusions they warrant. What follows in this section has reference chiefly to chubs but contains incidental references to commercially valueless bloaters that are taken with them. The reading of this section may be undertaken more profitably, perhaps, after page 476.

The term "chubs" is said first to have been applied to deep-water Leucichthys by the Chicago markets. The fishermen also call them "longjaws," "bluefins" (abbreviated to "jaws" and "fins"), "tullibees," "mooneyes," and "ciscoes." All of these names are used locally in varying senses and are not applied to the same fish by fishermen in different parts of the lakes; but wherever any of the above colloquial names is current any one of them may be used to designate a catch containing all the species. All are fat, herringlike fish, which inhabit the deeper waters.

In the Federal statistics all species of Leucichthys have been grouped together as "ciscoes," and the total of "ciscoes" has been from one-third to one-fourth of the entire output of the Great Lakes. The chubs have made up a variable but considerable part of this total.

Chubs occur in all the lakes except Erie. In Lake Nipigon, though certain species apparently are abundant, they have not yet become marketable. In Lake Ontario there are now only three species that probably are abundant enough to be taken in commercial quantities, but few examples of these species ever attain sufficient size to be captured by the 3-inch gill net (which is the minimum mesh allowed), so that these fish here have no economic significance. In Lake Superior the bluefin (*nigripinnis*) was commercially very important for a few years at the beginning of the century, but now it is commercially extinct. Of the other species, *zenithicus* is the only large chub that is common enough to be caught in commercial quantities. It has had little favor with the markets because of its thin body and only a few have ever been caught. The chub-fishing industry for years has been important on Lake Michigan, where it is supported by no less than seven species—*johannæ*, *alpenæ*, *zenithicus*, *reighardi*, *nigripinnis*, *kiyi*, and *hoyi*. It is important on Lake Huron, also, where it is sustained by four species only. *Reighardi* is not known to occur in the lake, and *kiyi* and *hoyi* do not grow large enough regularly to gill in chub nets.

Chub fishing started on Lake Ontario as early as 1860. The fish taken at this time were called ciscoes and bloaters instead of chubs. This fishery was carried on chiefly off the western and southern shores of the lake and did not attain sufficient proportions to affect more than the local fish trade. By 1900 the fishery was exhausted, and one of the species that sustained it apparently was exterminated. On Lake Michigan, so far as can be learned, chubs were being taken as early as 1869.

The first fish of this kind were caught for the salt-fish trade, and not until there was a demand for smoked fish did chub fishing flourish. Toward the end of the last century the chub supply of Lake Michigan could no longer easily supply the demand and the bluefins were marketed from Lake Superior. For about 10 years, or up to about 1907, these fish were caught and then suddenly became commercially extinct. About 1902 the use of small-meshed nets was begun on Lake Huron, and since about 1910 chubs have been sold at some time out of every port that could produce them. Lakes Michigan and Huron remain, then, the source of the chub supply. What follows pertains particularly to these two lakes.

Chubs are not sold fresh in the markets at any of the ports where taken. However, if properly cooked, the fresh flesh is not inferior to that of the whitefish, according to many. The bulk of the catches has been forwarded to Chicago or other midwestern cities for smoking. Thus prepared, the flesh is very palatable.

In late years the chub supply exceeded the demand largely because of the substitution of species of Lake Winnipeg Leucichthys and the Lake Erie herring. The former are inferior in quality and were used only in winter, when the Great Lakes supply was largely shut off. Since the wide use of 2½-inch netting for chubs on Lake Michigan and the consequent capture of small fish, the Erie herring, or cisco, competed strongly with the chubs, even to the extent of displacing them in the Chicago markets.

With the failure in 1925 of the Erie cisco, of which some 15,000,000 to 40,000,000 pounds had been marketed annually, the New York markets lost their supply of fish for smoking and Chicago buyers faced the competition of New York buyers in the chub market. Contracts for chubs were let at fancy prices, and where two years before the fishermen had to fish chubs at the pleasure of the buyers, in 1926 the tables were turned completely and chubs became the principal product of the lakes that could supply them. Where formerly only occasional fishermen had chub gangs, in 1926 everyone who could acquire the netting began the pursuit of the severely depleted schools.

Gill nets, which in Wisconsin,[3] Illinois, and Indiana are of 2½-inch, in Michigan of 2¾-inch, and in Canada of 3-inch stretched mesh, are used to catch the fish. The nets commonly employed are about 5 feet deep when in use and are set on the bottom at depths of 10 to 100 fathoms. In Lake Huron the nets are set, by preference, in water of 60 to 75 fathoms, where water of such depth is accessible. At the northern and southern ends of the lake 50 fathoms is the maximum depth easily reached by the fishermen. While there is deeper water in the two lakes and the fishermen have taken chubs in it, they prefer to keep their nets out of it. Unless the lines of the nets are new, there is danger that they will part from the strain that is imposed on them in lifting them from more than 75 fathoms of water.

"Mud" bottom is preferred by all chub fishermen. This bottom (judging from the samples brought up in the slits of the leads and from the descriptions of the fishermen) has the physical properties of clay and may be gray, blue-gray, yellow, or red in color. It is designated as clay on the United States Lake Survey charts, though in some areas, especially in Georgian Bay and in Lake Huron off Tobermory and Southampton, the chub nets are set in areas designated on the chart as mud.

[3] The new Wisconsin law reads that after July 1, 1926, the mesh may not be less than 2⅝ inches.

The bottom here is mucky in character and black, according to the fishermen. The most favorable bottom is soft; so soft that the sounding lead (a window weight of 3 to 4 pounds is commonly used) sinks for several inches into it. The leads of the nets likewise may sink into the mud and often drag the lower portions of the net with them. The extent to which the nets have been buried in the bottom is indicated sometimes by the adherence of bottom material to its threads. The boats may run as far as 50 miles from their harbor in search of suitable bottom and water of appropriate depth. The nets are lifted every third to fifth day.

The fishermen believe that the chubs swim in schools. This belief is based on the occurrence of the fish in numbers in some parts of the nets while they may be absent or less abundant in other parts. The coregonids of Europe (Fatio, 1890; Smitt, 1895) are known to be gregarious, as are also the other coregonids of the Great Lakes, and it is not improbable that the opinions of the fishermen are correct in this particular.

These schools are believed to be very sensitive to currents. The chub catchers welcome unsettled weather, when the existence of strong currents is supposed to drive the fish into the deepest water from the shallow water, or, if the fish are swimming high, from the upper layers to the bottom. We know that there are undercurrents in every lake subjected to wind action, which are the return flow of waters accumulated by the wind, and it is entirely consistent to believe that the more violent the wind the more violent will be these currents. The fishermen certainly find that during heavy storms all manner of débris and even logs are carried into their nets by the currents in the shallower waters, and they likewise believe that these violent winds increase the catches of the chub nets. If it can be determined to what depths these wind-produced currents penetrate, then, if the fishermen are correct in their assumption that the chubs avoid them, the lower limits of the stratum to which the chubs rise when they are not on the bottom will be defined.

Harrington (1895) showed the direction of the prevailing surface currents of the Great Lakes. There is no other literature on currents in the Great Lakes, so far as I am aware. The fishermen, in their experience, have obtained some data on the depths to which currents are active. For example, it is a matter of common knowledge among gill netters of the upper lakes that during storms their nets off open shores are not safe from destruction by current-carried débris in less than about 20 fathoms. In certain localities, as in channels and around islands, currents commonly are evident at greater depths. The depths to which these wind-produced currents are felt depend probably on the season of the year. When the difference in temperature between surface and bottom waters is least (as in spring and fall) the resistance of the water to mixing is slight, and at such times it is conceivable that in a lake as large as one of the Great Lakes the winds might affect the waters even to a depth of 60 fathoms. On the other hand, in the summer it is improbable that, at least in the upper lakes, such currents are conspicuous in their effect in water much deeper than 20 fathoms. In Lake Ontario it is certain that in summer the currents off open shores may be strong enough to damage nets in water as deep as 30 fathoms. A vertical series of temperature readings made in the lakes in summer would show, by the location of the thermocline, to what depths currents were active.

Drummond (1890) published a series of temperatures taken in Georgian Bay on July 27, 1888, which indicates that the thermocline for the bay was around 10 fathoms. A few temperature readings that I took in Lake Huron in September of the years 1917 and 1919 (see Table 12) indicate that the thermocline was somewhere between 15 and 35 fathoms, but probably a great deal higher than 35 fathoms, as Drummond's records indicate for Georgian Bay. Figures given in the same table show that the thermocline in Lake Nipigon in late July, 1922, was around 12 fathoms and in Lake Michigan in August, 1920, above 24 fathoms. Records for Lake Superior (in Table 13) indicate that on August 5 and 10, 1922, it was around 5 fathoms, except in Black Bay, where, on July 20, there was no evidence of a thermocline at 8 fathoms. Figures given by Coleman (1922) show that in Lake Ontario, on October 3, 1922, the thermocline was around 20 fathoms.

In Lake Nipigon, on July 28, 1922, there was no evidence of warming at 56 fathoms. The studies of Clemens, however, show that winds may lower the thermocline considerably and the bottom waters may be warmed slightly even to greater depths. In Lake Michigan the deepest temperatures recorded in August and October, 1920, at 40 and 49 fathoms, respectively, showed a fraction of a degree above the temperature of maximum density; and in August, 1894, Ward (1896) found about the same temperature there down to 72 fathoms. In Lake Huron the temperature of maximum density was reached on September 12, 1917, at 65 fathoms and on September 18, 1919, at 60 fathoms. In Lake Superior, the temperature of 4° was obtained on August 24, 1921, at 54 fathoms and on June 14, 1922, at 25 fathoms. Coleman's (1922) figures for Lake Ontario show no warming at 50 fathoms on October 3, 1922. It may be noted that bottom temperatures of 4° in depths of more than 50 fathoms also have been recorded in summer from Cayuga and Seneca Lakes in New York.

These data indicate that during the warmest part of the year there is little mixing of water by wind action in any of the lakes below 20 fathoms, and at depths of 40 fathoms currents had not brought about the admixture of warmer surface water and bottom water in volume sufficient to raise the bottom temperature more than a fraction of a degree above 4° C., the lowest temperature that could occur on the bottom in summer. Of course, temperature penetration depends largely on the amount of wind action, and the more continued and violent the winds in summer, the deeper would be their effects.

It appears from the foregoing that in summer the wind-produced currents are relatively ineffective in more than 40 fathoms. In the spring and fall, when the water is colder, currents are possible, of course, to greater depths. With no more data on currents or temperatures than are at present available it does not seem profitable to speculate further on the probable effect of these factors on the movements of the chubs, especially as it is not known how sensitive they are to differences in the rate of water movement in their environment.

The chub fishermen know relatively little about the spawning season of any of the species. In several localities on Lake Michigan and Lake Huron *alpenæ* and *zenithicus* become the objects of special fisheries during their spawning season, and out of a few ports on Lake Michigan the spawning *hoyi* are sought for; but only occasional persons here and there know anything about spawning runs of other species of chubs. In fact, many of the fishermen believe that the chubs spawn all

the year round. This belief is based on the observation that eggs are found free in the body cavity of an occasional specimen during the greater part of the fishing season. Of course, in Lake Michigan, where some species may be spawning during every month except June and July, such observations may well pertain to individuals spawning normally; but in Lake Huron, where the spawning season of the four species falls between August and January, some other explanation must be sought. It does not follow that such specimens are spawning. In most bony fishes the eggs are formed within a membranous ovisac and are carried from this to the genital opening by means of an oviduct continuous with the ovisac. There are no openings connecting ovisac or oviduct with the body cavity, and therefore the eggs can not get into the body cavity on their way to the genital opening.

In Coregonidæ the oviduct is short and not continuous with the ovisac, so that the eggs, after leaving the ovary, can get into the body cavity. It has been supposed that the normal course of the eggs after leaving the ovaries was to fall into the body cavity and thence to find their way out through the short oviduct. Kendall (1921) has shown that the eggs probably pass along a trough formed by the mesovarium, and that normally they do not escape into the body cavity. Should any eggs get into the body cavity and remain there after the fish have left the spawning grounds they would be noticed easily when the fish are dressed. Certain fishermen have told me that they sometimes find eggs in the body cavity of the lake trout in summer. Such eggs, they state, are much enlarged at this time. The retention of eggs in the body cavity has been recorded at least once in literature. B. G. Smith (1916) states that in many specimens of Cryptobranchus a few eggs are still to be found in the body cavity after spawning. It is probable, therefore, that what the fishermen observe outside of the spawning season are eggs that have been thus retained in the body cavity, and there is then no evidence that the chubs deposit their eggs at irregular intervals throughout the year.

It has already been stated that four species of chubs are found in Lake Huron and seven in Lake Michigan. Virtually every haul from the chub nets contains at least a few representatives of each species, together with the smaller chubs and bloaters that may be caught in nets with meshes of any size, even though they could pass through a mesh 10 abreast. Large chubs, also, not rarely become entangled in nets of mesh too coarse to gill them. Little is known concerning the proportion in which the various species occur at the various locations in the lakes at different seasons. What observations I have made will be recorded under each species concerned. The fishermen themselves make no distinction between the species, and consequently their records show nothing but the weight of the lift and sometimes the location of the gang lifted. Some of these records show marked fluctuations in the abundance of the chubs from month to month. In certain instances, with the aid of the results of the examinations of the chub lifts, these fluctuations can be ascribed definitely to the changes in the behavior of certain of the species of chubs. In Tables 14 and 15 are given statistics prepared from these records for 5 tugs from 5 ports on Lake Huron and for 3 tugs from 3 ports on Lake Michigan, each of which operated large chub gangs. For each tug the total and average weights of the catches are given for each month as long as fishing operations were continued during the year. Such con-

clusions bearing on the behavior of the fish as appear warranted from the data at hand are added.

Off Cheboygan (35 to 50 fathoms) chubs are not present on the grounds until May. The lifts increase slightly in weight in June and then fall off until September. From the middle of September until the middle of October the biggest lifts are made. After the latter date the lifts dwindle to almost nothing (see p. 399), and the nets are pulled out. Trout and whitefish are then running toward shore, and the 2¾-inch nets are laid up until the following May. The increased lifts for September and October point to a spawning run. Examination of the lifts taken during the September–October period shows that only *zenithicus* is being caught and that all the fish are spawning. It appears from the foregoing that the chub schools leave the shallow area at the north end of the lake in the fall and that they do not return until the following summer. Furthermore, only one species, *zenithicus*, is left on the grounds after the middle of September, and this species seeks these grounds to spawn. Further details of the spawning habits of this species will be found in another place.

Records of the Alpena, Southampton, and Duck Islands tugs present a different aspect. The tugs from these three ports fish in the vast central basin of the lake, which lies within the 60-fathom contour line. (See fig. 5.) The conditions in this area, as shown on the hydrographic map, are fairly uniform as to bottom and depth, and it is not surprising, therefore, that the records are similar for the three ports. The most striking feature of these records is the decline in the average weight of the lifts in September. The Duck Islands boat usually pulls in her nets before September, and the Southampton tugs neglect their nets in September for the trout. Both ports fish only large-meshed nets thereafter. This sharp decline is due apparently to the departure of most of the fish from the grounds. Examinations of the lifts made during September off Alpena showed that *johannæ* was the predominant element in the catches but that virtually all these chubs were individuals that, judging from the development of the sex glands, would not spawn until another season. Only an occasional ripe female was found. The inference follows that the schools of mature fish had moved to their spawning grounds, leaving the immature fish behind. Additional data to support this inference are given under the discussion of the breeding habits of the species in question. The Alpena lifts increase again in November, and this increase may be due to their return to the grounds. The fluctuations from month to month before September follow no constant course and can not be explained at present.

Unlike the other records, those for Harbor Beach show no marked increase or decrease in the average size of the lifts for the season. A general decline is apparent, however, from August until the nets are pulled out at the end of October. No explanation for this decrease suggests itself.

It is probable, from the foregoing, that the chub schools in the northern, southern, and central sections of the lake are differently constituted and that the successful catches of the boats fishing in these areas do not always depend on the same species. Many more observations must be on the proportions in which the four species are found in the lifts at different times and places before more can be read from the records of the commercial boats.

On Lake Michigan there are many more ports that fish chubs than on Lake Huron, but I have been able to obtain records from only three boats. Two of these fish in the northern basin, and several examinations of their catches indicate that they depend on the same species of chubs, the longjaw predominating. At Charlevoix the records show an even average through the season until November, when the lifts fall off. The Northport records indicate that the summer fishing is light (the gangs were pulled in in July and August), but the November and December lifts are relatively heavy. The records may be explained by assuming that the Charlevoix boat did not find the longjaw in the spawning season in November, while the Northport boat did.

The other records are for the southern basin, where several species of chubs are known to occur abundantly at times. The interesting features are the heavy lifts in August, October, and November. It is not known what occasioned the increased lifts in August, but in the fall the longjaw and the short-jawed chub (especially the latter) are known to spawn on these grounds. In February and early March the bloaters spawn here, too, but there are no figures of production for these periods.

The various records may not be set against one another to compare the relative abundance of chubs at each port. First, the nets employed by the Ontario boats are 3-inch, by the Indiana boats 2½-inch, and by the rest 2¾-inch. The statistics are not of the same years; they do not show the length of the nets operated nor the period of time each net was in the water before lifting; nor is any allowance made for the superior ability of the pilots of certain vessels in operating their nets. Each fisherman has his own ideas as to how many leads there should be on a given piece of net, how it should be seamed on the lines, at what speed the boat should run to set, in what direction the gang should run, etc. The data presented are sufficient, however, to give an idea of the value of these fish from the commercial point of view.

Conservation legislators nowhere have recognized the chubs, except to regulate the size of the mesh used to catch them. In spite of unrestricted fishing, the chubs still hold forth, but in much diminished numbers, so far as can be learned from the fishermen's statements. Unfortunately, no statistics are available for comparing catches of different periods of years. Unless accurate records were available for a considerable number of years on the same grounds, and unless these showed the weight of the catches, the length of the nets employed, and the location of the fishing grounds, no judgment could be formed as to the past and present abundance. While records that answer most of these requirements are available for the last four or five years, they show nothing conclusive. Every fisherman recognizes the fact that one season may bring very poor fishing for various reasons, while the next may bring more fish than have been known for several preceding years. Hence, average catches for different periods of years long enough to eliminate annual fluctuations, and expressed in terms of net length, must be compared in order to determine whether catches have increased or diminished over a particular area.

No statistics of production are necessary to show that chubs are much less abundant now than formerly. A few facts of the history of the industry will show to what extent they have been depleted. The first chub fishermen used nets of 3 to 4 inch mesh. Little by little the meshes employed grew smaller as the fish grew less abundant, until many of the chub fishermen are now using about the smallest

mesh that will take a marketable fish. In 1920 chubs were so scarce in Lake Michigan that many boats had to quit fishing for them, even with a minimum mesh. In Lake Huron the schools are less depleted because the drain on their numbers has been less severe, but here the same sort of situation obtains. The Canadian fishermen, with their minimum 3-inch mesh, have had to give up fishing on grounds where the American fishermen competed with their 2¾-inch nets; and even where 3-inch nets were used exclusively, as in Georgian Bay and at Southampton, the production has dwindled. Chub fishing was begun from Southampton about 1910, 10 to 12 miles WNW. of the city. After three years the catches began to fall off on these grounds until a point was reached at which the nets were operated on a narrow margin of profit. Efforts of the tugs to find new grounds have proved unsuccessful so far. Inside Georgian Bay and at Tobermory matters appear to be still worse. Here the industry began about 1912, and at no time have more than four or five small gasoline boats per year been engaged in chub fishing. At every port on the bay fishermen say that four nets now will not catch what one caught formerly. They say that the nets on the old chub grounds now are filled with the lawyer (*Lota maculosa*). Whether the lawyer preys on the chub and is responsible for the disappearance of the latter is a question. While the decrease in the abundance of the fish has not been marked on the American shore, nevertheless the consensus of opinion among American fishermen indicates that the fish are becoming less abundant. Since about 1917, it has been necessary for every tug to increase the length of its gangs to maintain the weight of its catches at the average level of preceding years.

Drastic protective measures must be enacted if the chubs are not to be exterminated completely. One of their number, the blackfin, already is extinct in three of the four lakes where it was commercially important, and their close relative, the Erie herring, which existed for years in almost fabulous abundance, is virtually gone. It seems quite impossible that the already seriously reduced schools should long withstand the drains of the present fisheries, the most intensive in the history of the lakes.

LEUCICHTHYS JOHANNÆ Wagner

THE CHUB (FIG. 14)

Argyrosomus johannæ Wagner, 1910, pp. 957–958, Lake Michigan; not of Jordan and Evermann, 1911.
Argyrosomus hoyi Evermann and Smith, 1896, pp. 310–312, in part, Lake Michigan.

Leucichthys johannæ, the chub, has been described from Lake Michigan and is known to occur in Michigan and Huron only of the Great Lakes series. In both lakes the species is represented by pale fish, which seldom attain more than moderate size for the genus, and which have few gill rakers on the first branchial arch, a more or less ovate body shape, as seen from the side, and a rather long snout and paired fins. The species prefers the deeper waters and spawns in late summer. The Huron race appears to differ from the typical form in having somewhat fewer scales in the lateral line and fewer scale rows, more pectoral rays, a somewhat longer head, snout, and paired fins, and to be somewhat more pigmented.

Type

The type is a male specimen (catalogue No. 87353, U. S. National Museum) 265 millimeters in length, taken "some 18 miles off Racine, Wis., in Lake Michigan, in

about 25 fathoms on July 3, 1906." Counts of certain multiple parts and proportional lengths for this specimen are shown in Table 17 and are repeated in the text description that follows.

Leucichthys johannæ of Lake Michigan

The chub is moderate in size, seldom longer than 3 decimeters (12 inches), with a maximum weight of about 1½ pounds. The fish is roughly fusiform in shape, moderately compressed, and elongate. The greatest depth is just in front of the dorsal and usually comprises 22 to 27 per cent of the total length. The width is about 48 to 53 per cent of the depth. The anterior dorsal profile rises rapidly and in nearly a straight line for about two-thirds the distance from the tip of the premaxillaries to the dorsal and continues to the dorsal in a curve with only a slight upward trend. From the insertion of the dorsal the contour slopes into the caudal peduncle in a more or less straight line. The ventral profile from the tip of the snout to the caudal peduncle is rather uniformly curved. The head is relatively long and of little depth, rather acutely triangular in side view. Its length is contained 4.2 [(3.8) 4–4.2 (4.4)] [4] times in the total length. The snout likewise is elongate, narrow, and acute in side view, and is contained 3.4 [(3.2) 3.3–3.6 (4)] [5] times in the head length. The premaxillaries usually are little or not at all pigmented and are oblique in position, meeting the horizontal axis of the head at an angle of 50° to 60°. The maxillary seldom is pigmented and never extends to the center of the eye. The lower jaw is moderately developed and usually equal to the upper, though often longer or shorter. The eye is moderate in size and is contained 4.5 [(4) 4.4–4.6 (4.9)] times in the length of the head. The gill rakers on the first branchial arch number 10+19 [(9) 10–12 (14)+(16) 17–20 (22)]=(26) 27–32 (36).[6] Scales in the lateral line number 82 [(74) 80–90 (95)]. Rows of scales around the body in front of the dorsal and ventrals number 41 [(38) 41–44 (46)], [7] in front of the adipose and anus 33 [(31) 33–37 (38)],[7] and around the caudal peduncle at its commencement 26 [(22) 24–26 (27)][7].

The dorsal rays are 10 [9–10 (11)];[8] anal rays 12 [(10) 11–13 (16)];[8] pectoral rays 17 [(14) 16–17 (20)]; ventral rays 11 [11–12].[9] The length of the pectoral fin is contained 2 [(1.5) 1.6–1.8 (2.1)] times in the distance from the pectorals to the ventrals. The dorsal margin of the distal third of the pectoral usually is strongly decurved. The length of the ventrals is contained 1.5 [(1.1) 1.2–1.5 (1.6)] times in the distance from their origin to the origin of the anal.

The color in life is silvery, with a more or less faint pinkish to purplish iridescence, which is strongest above the lateral line and absent on the belly. Close examination reveals a pale slaty bluish to pea green on the back below the silvery layer. This color is most pronounced in front of the dorsal. It changes to blue-green halfway to the lateral line, and that color continues to the white belly. The slaty tone is

[4] The figures in brackets, unless otherwise stated, are based on an examination of 74 specimens, ranging in length from 212 to 288 millimeters.

[5] Forty-seven specimens.

[6] One-hundred and twenty-two specimens.

[7] Thirty specimens.

[8] Forty-seven specimens.

[9] Ten specimens.

due in part to the presence of heavy pigment deposits bordering the exposed surfaces of the scales on the dorsal area. The top of the head is cartilaginous white, usually obscured with abundant, fine pigment dots, with four small patches of green lying in the frontal bones on each side of the carina. Three of these patches are situated posterior to the center of the eye and are nearly contiguous, extending backward to the occiput. The first is the largest and is rounded triangular in shape. The other patch is situated on the side of the carina and is club-shaped. Its narrow end extends backward and inward to meet its companion of the other half of the head. There is also a small bit of green in the heavily pigmented cartilage on the side of the head in front of the eye. The cheeks are silvery, without color, excepting a small patch of green on the dorsal angle of the operculum. The maxillaries, usually the premaxillaries, preopercula, and mandible are whitish and usually unpigmented, though all but the maxillaries (not including the jugals) and the preopercula often show a few pigment dots.

The fins are whitish, translucent, all but the ventrals more or less pigmented. The cranial margin and a wide distal band of the dorsal, the lateral borders, the distal third of the longest and half of the shortest rays of the caudal are smoky to black in hue. The dorsal margin and inner surface of the pectoral often are sprinkled sparingly with black. Often pigment dots are present on the membranes that connect the anal rays.

All color fades after death, and after preservation the silvery tone usually disappears, leaving characters of pigmentation more conspicuous. The pigment, which in life is evident on the entire dorsal surface, is revealed in diminished abundance on the sides above the lateral line. Below the lateral line and on the cheeks pigment is scattered.

Most, if not all, of the males acquire pearl organs in the breeding season. All the males taken off Rock Island, Wis., on August 19, 1920 (record 1), and most of those taken later in that year out of other ports showed pearls. Pearls are present on all the scales, except often on those of the dorsal and ventral surfaces caudad of the dorsal and ventral fins, and also on the four surfaces of the head, including the mandible and maxillary. There are indications on some specimens that faint pearls are developed on at least some of the fins, especially on the abdominal ones. The pearls on the head are smallest, are irregular in shape and size, and are irregularly distributed. With the exception of the dorsal and ventral areas and the scales of the lateral line (where the pearls may be irregular in shape and distribution, unequal in size, and sometimes two or more in number), there is only one pearl on each scale. The lateral-line scales have two pearls each, one on each side of the pore, the two often fusing over it. The pearls on the belly anterior to the ventrals are borne on a somewhat thickened epidermis. On the sides, pearls are well developed on the first three or four rows above the lateral line and on the first five or six below. In shape these pearls are rounded to oval, usually longer than wide, flattened, situated at or near the tip, and extending from one-half to two-thirds the length of the exposed portion of the scale. They are largest on the anterior two-thirds of the two rows on each side of the lateral line, where they occupy one-fourth to one-third of the exposed surface, and diminish more or less gradually in size dorsad, ventrad, and caudad.

VARIATIONS

Racial variations.—Specimens collected from no area in the lake show distinctive characteristics, and there are not enough specimens in my collection to show whether there are races distinguished by average differences in systematic characters.

Size variations.—Only two specimens smaller than 200 millimeters have been seen. These measured 181 and 190 millimeters. There was one of each sex, and both were sexually mature.

COMPARISONS [10]

Johannæ resembles most closely *alpenæ.* It is distinguished from this species principally in having a less elliptical body outline as seen from the side, a more elongated and pointed head, fewer gill rakers on the first branchial arch, longer paired fins, and more lateral-line scales. It has also, on the average, a larger head, a shorter mandible, and spawns about three months earlier, so that at certain seasons, at least, the state of ripeness of the sex products will serve as a distinguishing character to separate the two species. The comparative figures for some of the above-mentioned characters follow:

Gill rakers:
- *johannæ,* (26) 27–32 (36).
- *alpenæ,* (33) 36–43 (46), with 86 per cent more than 36.

Lateral-line scales:
- *johannæ,* (74) 80–90 (95), with 35 per cent more than 85.
- *alpenæ,* (71) 78–85 (96), with 10 per cent more than 85.

Pv/P:
- *johannæ,* (1.5) 1.6–1.8 (2.1), with 16 per cent more than 1.8.
- *alpenæ,* (1.6) 1.9–2.2 (2.5), with 89 per cent more than 1.8.

Av/V:
- *johannæ,* (1.1) 1.2–1.5 (1.6), with 6 per cent more than 1.5.
- *alpenæ,* (1.2) 1.4–1.7 (1.9), with 54 per cent more than 1.5.

Johannæ is distinguished from *zenithicus* principally in the number of gill rakers on the first branchial arch, in the pigmentation of the premaxillaries and maxillary, in the length of the paired fins and mandible, and in body shape. *Johannæ* always has less than 37 gill rakers on the first branchial arch; *zenithicus* has more than 34. The premaxillaries and maxillary, particularly the maxillary, usually are immaculate in *johannæ* and pigmented in *zenithicus.* The value for Pv/P for *johannæ* is (1.5) 1.6–1.8 (2.1), with 16 per cent more than 1.8; for *zenithicus* (1.7) 2–2.2 (2.6), with 89 per cent more than 1.8. The mandible also is shorter than the upper jaw, and the slope of the body contours, as seen from the side, is more gradual in *zenithicus.* The state of development of the ova in the ovaries, also often will serve to separate females, inasmuch as *johannæ* spawns in August and September and *zenithicus* in November.

Johannæ is distinguished from *reighardi* principally by the body shape, which in *reighardi* is much more terete; by the fewer gill rakers on the first branchial arch, longer paired fins, and longer mandible, snout, and maxillary. *Johannæ* also has, on the average, more lateral-line scales, a proportionally larger head and smaller

[10] Figures given in this section for proportions are based on specimens 200 millimeters or more in length, except for *artedi,* where the limit is 225 millimeters. Counts are given for specimens of all sizes.

eye, and is much less pigmented throughout. The mandible, maxillary, and premaxillaries, especially, usually are immaculate or nearly so in *johannæ* and conspicuously pigmented in the other. As *johannæ* spawns in August or September and *reighardi* in May or June, the state of ripeness of the sex glands may be helpful often in separating the species. A comparison of certain characters of the two species follows:

Gill rakers on the first branchial arch:
- *johannæ* (26) 27–32 (36), with 7 per cent more than 33.
- *reighardi*, (30) 34–38 (43), with 90 per cent more than 33.

Pv/P:
- *johannæ*, (1.5) 1.6–1.8 (2.1), with 8 per cent more than 1.9.
- *reighardi*, (1.7) 2–2.5 (2.8), with 96 per cent more than 1.9.

Av/V:
- *johannæ*, (1.1) 1.2–1.5 (1.6), with 7 per cent more than 1.5.
- *reighardi*, (1.2) 1.4–1.7 (1.9), with 42 per cent more than 1.5.

The chub is separable at once from the blackfin by its less numerous gill rakers on the first branchial arch, which in the former are not more than 36 and in the latter not less than 41, and by the absence or sparseness of pigmentation on the premaxillaries, maxillary, mandible, and the ventral fins, which in *nigripinnis* are usually densely pigmented. The chub has a longer snout, also, a narrower and more attenuated head, a smaller eye, and a much paler body and fins. Females often may be distinguished by the state of development of the ovaries. The chub spawns in late August and early September and the blackfin in late December and early January.

Only small *johannæ* are comparable with *kiyi*, as *kiyi* attains less size than most of the species of the genus. Specimens of the two species may be separated by the number of gill rakers on the first branchial arch, which in *johannæ* are never more than 36 and in *kiyi* are not known to be less than 34; and by the paler mandible, premaxillaries, and maxillary, which in *johannæ* are immaculate, or, in the case of the first two, but sparingly pigmented and in *kiyi* abundantly pigmented; and by the character of the body, which in *kiyi* is conspicuously thin and frail. *Johannæ* also has a smaller eye and somewhat shorter paired fins. Females usually can be distinguished by the state of development of the ova, as *johannæ* spawns in August and September and *kiyi* probably in October.

Hoyi also does not regularly grow as large as *johannæ*, and the two species are at once distinguishable by the number of gill rakers on the first branchial arch, which in *johannæ* are not more than 36 and rarely more than 33, and in *hoyi* not less than 37; by the body shape, which in *johannæ* is rather ovate in side view and in *hoyi* elliptical; by the pigmentation rarely present on the premaxillaries, mandible, and maxillary of *johannæ* and always present on those parts in the other; by the more numerous lateral-line scales, which in *johannæ* number (74) 80–90 (95), with 95 per cent more than 77, and in *hoyi* (60) 67–77 (84), with 7 per cent more than 77. The snout in *johannæ* is much longer, so that the head, viewed from the side, is more attenuated. *Johannæ* spawns in August and September and *hoyi* in March, so that the state of development of the sex organs often is a criterion to separate the two species. In *hoyi* the mandible is frailer and more hooked.

Johannæ is at once separable from *artedi* by the fewer gill rakers on the first branchial arch, which are not known to be more than 36 in the former and not less than 41 in the latter; by the body shape, which in *johannæ* is less elliptical, as seen from the side; and by the longer paired fins. The comparative values for Pv/P and Av/V follow:

Pv/P:

johannæ, (1.5) 1.6–1.8 (2.1), with 16 per cent more than 1.8.
artedi, (1.6) 1.9–2.2 (2.6), with 94 per cent more than 1.8.

Av/V:

johannæ, (1.1) 1.2–1.5 (1.6), with 6 per cent more than 1.5.
artedi, (1.4) 1.6–1.8 (2.3), with 89 per cent more than 1.5.

Johannæ has usually no pigment on the maxillary, premaxillaries, and mandible, while in *artedi* these parts are pigmented; the general color of the latter, including the fins, is much darker. *Johannæ* has a relatively longer snout and maxillary, a smaller eye, larger head, more body depth, and more pectoral rays. *Johannæ* spawns in August to September and *artedi* in November, so that often at least the females can be separated by the state of development of the sex organs.

GEOGRAPHICAL DISTRIBUTION

Data on the occurrence of the chub in Lake Michigan are assembled in Table 16 and are shown platted on a map of the lake in Figure 4. There are 17 records made by me from the commercial chub nets of 2½ to 2¾ inch mesh set out of 13 ports on the lake. Comparison with a similar table prepared for *hoyi* (Table 56) makes obvious the fact that while the chub may be taken out of most of the ports visited, it is by no means always present in all the lifts made from these ports. The conclusion may be drawn, however, that the chub occurs throughout the lake at suitable depths and on suitable bottom.

BATHYMETRIC DISTRIBUTION

The records in Table 16, from the commercial nets set for deep-water Leucichthys or "chubs," show *johannæ* to have been taken at depths of 30 to 90 fathoms. Certain other examined lifts of these small-meshed nets, made at depths of 22 to 50 athoms, took no *johannæ*, but some of these were made on or near the spawning grounds of other species, and it is understandable that *johannæ* should not have occurred among them. Lifts of this kind were made on March 24, 1919, off Milwaukee, Wis., in 50 fathoms, and on March 2, 1921, 21 miles NNW., and on March 4, 1921, 15 miles NW. by N. ½ N. of Michigan City, Ind., in 28 to 30 fathoms on the spawning grounds of *hoyi;* on November 15, 1920, 20 miles ESE. of Milwaukee in 28 to 35 fathoms, and on November 19, 1920, 10 miles NNW. of Michigan City, Ind., in 18 fathoms, and 17½ miles NW. by N. ¾ N. in 32 fathoms on the spawning grounds of *zenithicus.* Sets of nets of suitable mesh, but which were probably in too shallow water or on grounds unsuitable for *johannæ,* were made on August 16, 1920, in Green Bay off Little Sturgeon and 8 miles south of Green Island, Wis., in 11 and 16 fathoms; on August 18, 1920, 4 miles west of Boyer Bluff, off Washington Harbor, Wis., in 18 to 24 fathoms; on September 24, 1920, 9 miles NNE. of Mil-

waukee, Wis., in 22 to 25 fathoms; on November 8, 1920, 18 miles NNW. of Michigan City, Ind., in 30 to 38 fathoms; on November 19, 1920, 17 miles NNW. in 28 to 32 fathoms; on August 10, 1923, 8 miles NNW. of Big Rock Point, Mich., in 45 to 50 fathoms, and on August 21, 1923, off Charlevoix at probably the same depth.

Besides the 2½ and 2¾ inch nets that are fished for Leucichthys, there are other sources of data on the occurrence of Leucichthys, which however, have yielded nothing bearing on *johannæ*—the 4 to 4½ inch whitefish and trout nets and the 1½-inch bait nets, both usually set at depths less than 40 fathoms. In the 4 to 4½ inch nets no chubs could gill, as no specimen of this species has been known to grow so large; but no individuals ever have been seen by me to have been entangled in its meshes. Fish caught thus are only accidental inclusions, however, and even small fish might actually be present in numbers and yet not be caught, so that the want of data from this source is not conclusive.

In the 1½-inch nets small individuals could gill along with the small *hoyi* and other Leucichthys, but no specimens of this species were seen in lifts of these nets made from 26 to 40 fathoms on June 23, 1920, off Northport, Mich.; on July 18, 1923, in West Grand Traverse Bay; on August 27, 1920, 4 miles west of Manistee, Mich.; on September 25, 1920, 5 miles E. ½ S. of Port Washington, Wis.; on September 28, 1920, 5 miles SE. by E. of Sheboygan, Wis.; on October 8, 1920, off Racine, Wis.; and on March 2, 1921, 14 miles NNW. of Michigan City, Ind.

No specimens occurred either in the special 1½-inch nets lifted from 4 to 16 fathoms on July 25, 1923, off Traverse City, Mich., from 8 to 12 fathoms on July 21, 1923, and from 15 to 25 fathoms on July 23, 1923, in Platte Bay, and from 8 to 10 fathoms on July 30, 1923, off South Manitou Island, Mich.

All the data thus show that at certain seasons, at least, the chub does not occur at depths of less than 30 fathoms and that it ranges to depths of 90 fathoms. It is likely that it goes even deeper. The small individuals, it appears, either do not consort with the small *hoyi* or else may not be found outside the 40-fathom contours.

RELATIVE ABUNDANCE

Throughout the summer and fall of 1920 small lifts were made from the chub nets at every port on the lake. Lifts examined during the season, including the lifts made out of Milwaukee and Michigan City on the spawning grounds of *zenithicus*, ranged between 20 and 180 pounds of fish to the mile of net when lifted after five nights. As never more than three fish are required to make a pound, it is obvious that fish were uncommon along the bottom. Lifts in which no fish of this species were taken are enumerated in the preceding section. Lifts in which only an occasional chub was taken were made as follows: On June 22, 1920, and on July 31, 1923, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms; on June 29, 1920, 5 miles N. by E. and on August 11, 1923, 3 miles NW. ½ W. of Charlevoix, Mich., in 35 to 65 fathoms; on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms; on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms; on September 23, 1920, 27 miles ESE. of Milwaukee, Wis., in 60 fathoms; on September 25, 1920, 18 miles E. ½ S. of Port

Washington, Wis., in 65 to 48 fathoms; on September 3 and October 11, 1920, 22 miles NW. by N. ½ N. and 20 miles N. by W. ¾ W. of Michigan City, Ind., in 30 to 40 fathoms (records 3, 5, 7–9, 14–18). Out of Frankfort, Mich., 9 miles north of Point Betsie, on October 4, 1920, in 60 to 70 fathoms, chubs made up 7 per cent of a lift of 1,400 pounds (record 13). On August 23, 1920, 12 miles E. by S. of the mouth of the Sturgeon Bay ship channel, in 60 to 70 fathoms, chubs made up 22 per cent of the total lift (record 2), but as its weight was only 50 pounds, few chubs were taken. Chubs were found abundantly only in one lift examined—when the nets were lifted on August 19, 1920, 20 miles E. ½ N. of Rock Island, Wis., in 71 to 90 fathoms (record 1). Out of a total lift of 900 pounds, about one-third were chubs and the rest *kiyi*.

According to the records, then, the chub has not been common in the chub hauls from less than 70 fathoms. The only set that took the fish in numbers was made from a depth of 71 to 90 fathoms, the deepest lift examined.

BREEDING HABITS

Only an occasional fish was seen previous to August, 1920, and these fish were not sexually mature. The specimens taken on August 19, 1920, 20 miles E. ½ N. of Rock Island in 71 to 90 fathoms, were chiefly pearled males, from which milt flowed freely. Females were not common and those taken were not yet ripe. While it is certain that these fish would spawn soon, it is not certain that they would spawn on the grounds where taken. Many of the stray fish taken up to October from other ports were either males with pearls or spent females. It is safe to state, then, that the spawning time for the species lies somewhere between the middle of August and the last of September. It is not known at what depths and on what bottom the species spawns.

Leucichthys johannæ of Lake Huron

The *johannæ* of Lake Huron is like the typical form in body shape but differs somewhat from it chiefly in the matters of certain proportions and of counts of certain multiple parts. A comparison of some of the systematic characters follows:

Gill rakers on the first branchial arch:
- Michigan, (26) 27–32 (36).[11]
- Huron, (25) 27–31 (35).[12]

Lateral-line scales:
- Michigan, (74) 80–90 (95).
- Huron, (67) 77–87 (91).

L/H:
- Michigan, (3.8) 4–4.2 (4.4).
- Huron, (3.4) 3.8–4.1 (4.3).

H/E:
- Michigan, (4) 4.4–4.6 (4.9).
- Huron, (3.9) 4.3–4.8 (5.3).

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[11] These figures for Lake Michigan are given for 122 specimens. Unmarked figures are given for 74 specimens ranging in length from 212 to 288 millimeters.

[12] Figures for gill rakers are based on 441 specimens, those for scales on 258 specimens. All other figures for Lake Huron, unless marked, are based on 219 specimens ranging in length from 200 to 332 millimeters.

H/S:
- Michigan, (3.2) 3.3–3.6 (4).[13]
- Huron, (3) 3.2–3.5 (3.6).

Pv/P:
- Michigan, (1.5) 1.6–1.8 (2.1).
- Huron, (1.3) 1.5–1.8 (2.1).

Av/V:
- Michigan, (1.1) 1.2–1.5 (1.6).
- Huron, (1) 1.2–1.4 (1.6).

Pectoral rays:
- Michigan, (14) 16–17 (20).
- Huron, (15) 17–18 (19).

Scale rows:
- Michigan, (38) 41–44 (46), (31) 33–37 (38), (22) 24–26 (27).[14]
- Huron, (36) 40–42 (45), (30) 32–35 (36), (22) 24–26.[15]

It appears that the Huron race has, on the average, somewhat fewer lateral-line scales and scale rows, more pectoral rays, a somewhat longer head and possibly snout, and paired fins. The number of specimens compared for proportions is 219 for Huron and 74 for Michigan, with those from Huron averaging longer. Inasmuch as in most fishes the head decreases in relative size with age, the smaller size of the Michigan specimens makes the difference in proportion more significant. The Huron form also shows more pigment. The premaxillaries are never immaculate, as in the Michigan form, but usually are as densely pigmented as the top of the head, and the fins (except the ventrals) are, on the average, somewhat more pigmented. Specimens from Georgian Bay sometimes have pigmented maxillaries, but the maxillaries of those from Lake Huron proper usually are immaculate.

The color in life is as in the Michigan form except for the details of pigment recorded above.

Males of the species in Lake Huron also acquire pearls in the breeding season. Males taken on October 6, 1919, in 70 fathoms off White Bluff in Georgian Bay still had traces of pearls. The females taken on this date were spent. It is assumed, then, that the breeding season was past and that the pearls of the males were declining. There were no features of the state of development observed to indicate that the full nuptial adornment of the Huron males would be different from that described for the males of Lake Michigan.

VARIATIONS

Racial variations.—Virtually all the specimens collected originated in Lake Huron off Alpena and in Georgian Bay. Making allowance for the greater size of the fish from Georgian Bay, where the net mesh is larger than in Lake Huron, there are no discernible differences in the systematic characters of the two groups except the detail of pigmentation previously referred to.

Size variations.—In Table 19, 20 specimens are extensively compared, half of them less than 200 millimeters in length and half of them more than 200 millimeters. In Tables 8 to 11 certain systematic characters are given for all the specimens of the collection similarly separated according to size. From these tables it may be seen

[13] Forty-seven specimens. [14] Thirty specimens. [15] Sixty specimens.

that the only differences recognizable in the two classes are differences of proportion. The head, expressed in terms of body length, is relatively though but slightly larger in smaller specimens. The most striking difference is shown in the ratio that exists between the measurements of the head and eye in the two groups. The complete data in Table 9 show that for the smaller specimens the eye is contained (3.6) 4–4.3 (4.5) times in the head length, while for the larger specimens the proportion is (3.9) 4.3–4.8 (5.3). The relation between the length of the head and its other parts appears to remain unchanged by growth. The pectoral and anal fins show a decrease in relative length with increased size. The larger fish are relatively deeper.

Most individuals that have attained a length of 195 millimeters have been found to be sexually mature. No mature specimens have been seen smaller than 165 millimeters. Maturity probably is determined by age rather than by the size of the specimen.

COMPARISONS [16]

Johannæ may be mistaken most frequently for *alpenæ*, though small specimens might be confused with bloaters or kiyis. *Johannæ* has fewer gill rakers on the first branchial arch, longer paired fins, more pectoral rays, a shorter and less-developed mandible, a less fusiform body shape (as seen from the side), and its head is more acutely triangular in side view. The chub spawns in September, while the longjaw spawns in November, so that the state of development of the sex organs often may serve to separate the two forms. The longjaw attains a greater size. A comparison of certain characters of the two species follows:

Gill rakers on the first branchial arch:
- *johannæ*, (25) 27–31 (35), with 7 per cent more than 31.
- *alpenæ*, (31) 34–40 (44), with 99 per cent more than 31.

Pv/P:
- *johannæ*, (1.3) 1.5–1.8 (2.1), with 23 per cent more than 1.7.
- *alpenæ*, (1.6) 1.8–2.1 (2.3), with 89 per cent more than 1.7.

Av/V:
- *johannæ*, (1) 1.2–1.4 (1.6), with 9 per cent more than 1.4.
- *alpenæ*, (1.3) 1.4–1.7 (1.9), with 72 per cent more than 1.4.

Pectoral rays:
- *johannæ*, (15) 17–18 (19), with 43 per cent more than 17.
- *alpenæ*, (14) 15–17 (18), with 3 per cent more than 17.

Johannæ differs from *zenithicus* in respect to length of mandible, which in the former usually is equal to the upper jaw and in the latter shorter; in the pigmentation of the maxillary, which is usually immaculate in the former and pigmented in the latter; in the shape of the body, which in side view is less elliptical in the former; in the fewer gill rakers on the first branchial arch; and in the longer head and paired fins. *Johannæ* also has, on the average, a longer snout and more pectoral rays and spawns about a month earlier. A numerical expression of the more significant characters follows:

Gill rakers:
- *johannæ*, (25) 27–31 (35).
- *zenithicus*, (34) 37–40 (44), with 89 per cent more than 35.

[16] Figures for proportions in this section are given for specimens 200 millimeters or more in length, except those for *artedi*, where the limit is 225 millimeters, and for *kiyi* and the specimens of *johannæ* compared with it, all of which are under 200 millimeters long. Counts are given for specimens of all sizes.

L/H:

johannæ, (3.4) 3.8–4.1 (4.3), with 20 per cent more than 4.
zenithicus, (3.9) 4.1–4.3 (4.5), with 77 per cent more than 4.

Pv/P:

johannæ, (1.3) 1.5–1.8 (2.1), with 10 per cent more than 1.8.
zenithicus, (1.6) 1.9–2.1 (2.3), with 82 per cent more than 1.8.

Av/V:

johannæ, (1) 1.2–1.4 (1.6), with 11 per cent more than 1.4.
zenithicus, (1.2) 1.5–1.6 (1.8), with 77 per cent more than 1.4.

Johannæ differs from *nigripinnis* in about the same manner as the chub of Lake Michigan differs from the Lake Michigan blackfin. They differ less, however, in the degree of pigmentation of the premaxillaries in Lake Huron. There is some pigment on the premaxillaries of *johannæ*, but they average much paler than in *nigripinnis*.

Only small *johannæ* are comparable with *kiyi*, for *kiyi* in Lake Huron is not known to grow large. *Johannæ* may be separated from *kiyi* by the fewer gill rakers, smaller eye, and less pigmentation. The number of gill rakers on the first branchial arch in *johannæ* is (25) 27–31 (35), in *kiyi* (34) 36–40 (44); H/E for *johannæ* is (3.6) 4–4.3 (4.5), with 72 per cent more than 4, and for *kiyi* (3.3) 3.6–3.8 (4). The maxillary in *kiyi* is almost always pigmented over at least half its surface, while in *johannæ* it is almost always white. *Kiyi* has also, on the average, longer paired fins, and the mandible is frailer, darker, and usually longer. The state of development of the ova will aid in separating females at certain seasons, for *johannæ* spawns at least a month earlier.

Johannæ is absolutely separable from *artedi* by the number of gill rakers, which in the former are not known to number more than 35 and in the latter not less than 40; and by the body shape, which is elliptical in side view only in *artedi*. *Johannæ* also has a longer, more attenuated head, longer snout, maxillary, and paired fins, and a smaller eye. The maxillary is always pigmented in *artedi* and seldom shows pigment in *johannæ*, and the body is generally much darker throughout in the former. The state of development of the sex organs also is an aid in separating the two, as *johannæ* spawns in September and *artedi* in November. The proportional characters referred to above are compared below:

L/H:

artedi, (4) 4.3–4.6 (5),[17] with 80 per cent more than 4.2.
johannæ, (3.4) 3.8–4.1 (4.3), with 1 per cent more than 4.2.

H/E:

artedi, (3.7) 3.9–4.3 (4.7), with 19 per cent more than 4.2.
johannæ, (3.9) 4.3–4.8 (5.3), with 87 per cent more than 4.2.

H/S:

artedi, (3.5) 3.7–4 (4.3), with 82 per cent more than 3.6.
johannæ, (3.1) 3.3–3.5 (3.6).

Pv/P:

artedi, (1.7) 2–2.2 (2.6), with 72 per cent more than 1.9.
johannæ, (1.3) 1.5–1.8 (2.1), with 2 per cent more than 1.9.

Av/V:

artedi, (1.4) 1.6–1.8 (2.1), with 90 per cent more than 1.4.
johannæ, (1) 1.2–1.4 (1.6), with 11 per cent more than 1.4.

The differences between *johannæ* and *hoyi* are given on page 461.

[17] Figures for *artedi* do not include the *manitoulinus* form.

GEOGRAPHIC DISTRIBUTION

In Table 18 are assembled all my data on the occurrence of the chub in Lake Huron. In Figure 5 these data are shown platted on the chart of the lake.

Lake Huron proper.—There are 33 records made by me for Lake Huron. Excepting records 7 and 9, these were made from boats that fished nets expressly for chubs and show the chub to range throughout the deeper American waters of the lake. Aside from the fact that conditions are similar on the Canadian side of the boundary line (from which it may be safely concluded that the species ranges in the Canadian waters also) there is evidence derived from the comparison of the records of the Southampton and Duck Islands boats, which fish in these waters, and those of Alpena tugs (see p. 346) that indicate that the chub actually is taken abundantly in this area.

North Channel.—No chubs have been seen from this region. Though the fishermen report Leucichthys off Gore Bay Light and off Meldrum Bay in 20 to 28 fathoms, there is nothing in the description of these fish to indicate that they belong to this species. On the contrary, in view of the large size of the fish reported and of the shallow water in which they are taken, it seems safe to conclude that they are not chubs.

Georgian Bay.—Records 34 to 39 establish the occurrence of the chub in Georgian Bay in summer and fall at depths corresponding to those at which it occurs in Lake Huron. There is no reason to believe that it does not range throughout Georgian Bay at similar depths at these seasons. From these data it appears that the chub ranges throughout Lake Huron and Georgian Bay, but that none occur in the North Channel.

BATHYMETRIC DISTRIBUTION

The records just reviewed deal mainly with the occurrence of chubs in the 2¾ and 3 inch chub nets set at 35 to 100 fathoms. In less than 35 fathoms no chub nets are set, so that the only sources from which evidence can be derived of the occurrence of the chub at depths less than 35 fathoms are (1) the 4½-inch trout and whitefish nets, (2) the four nets of 2¾-inch mesh that were set under my direction with the 4½-inch nets, and (3) the 1½-inch nets. (See p. 373.)

1. *The 4½-inch trout and whitefish nets.*—Record 7 shows a single specimen taken on September 7, 1917, in 16 to 20 fathoms. This fish was too small to be gilled in the nets.

2. *The 2¾-inch nets set with the trout and whitefish gangs.*—The nets lifted with the 4½-inch nets on September 17, 1917, in 15 fathoms, on September 19, 1917, in 30 fathoms, September 26, 1917, in 17 fathoms, and November 2, 1917, in 15 fathoms, to determine whether the chub occurred in greater numbers than was shown by the captures in the 4½-inch nets themselves brought in no chubs. The net of the 19th brought in 9 longjaws and 6 short-jawed chubs.

3. *The 1½-inch bait nets.*—From the 1½-inch bait nets at 30 fathoms only one specimen was taken (record 9). Other lifts of these nets at a similar depth at Cheboygan, Mich., on October 15, 1919, at Alpena, Mich., on September 16, 1919, and at Harbor Beach, Mich., on December 9, 1917, and on March 15, 1919, revealed no examples of this species.

Thus my records show that the extreme range of the species when not spawning extends from 16 to 100 fathoms. Examples are taken but rarely in less than 35 fathoms, and therefore 15 fathoms probably is the lower limit of the range. There are no data that fix the upper limit. Probably the chub occurs also in the deepest waters of the lake.

RELATIVE ABUNDANCE

From the chub nets in 50 fathoms and deeper lifts were examined on 22 occasions. (Examinations of the lifts off Cheboygan, Mich., and Rogers, Mich., at 35 to 50 fathoms, in which only spawning *zenithicus* were taken, have no value in determining the abundance of other species of chubs at these depths, and therefore they are not included in this number.) The majority of chubs seen in Lake Huron were yielded by lifts out of Alpena, Mich. Lifts made at the center of the lake in 60 to 80 fathoms northeast and east of Alpena on September 7, 1917 (record 8), September 10, 1917 (record 10), September 12, 1917 (record 11), September 14, 1917 (record 12), September 17, 1917 (record 13), September 26, 1917 (record 20), and October 17, 1917 (record 21); on August 7, 1920, 19 miles NE. ½ N. of Thunder Bay Island in 60 to 65 fathoms (record 27); on August 30, 1919, 18 miles N. by E. ½ E. of Thunder Bay Island in 60 to 64 fathoms (record 23); on September 3, 1919, 28 miles E. ¼ S. of the can buoy in 60 to 64 fathoms (record 24); and on June 30, 1923, 17 miles NE. ¾ N. of Thunder Bay Island in 65 to 70 fathoms (record 29), contained 50 to 90 per cent chubs. Lifts from the center of the lake made on September 21, 1917 (record 18), September 24, 1917 (record 19), October 20, 1917 (record 22), and on June 28, 1923, 19 miles northeast of Thunder Bay Island in 60 to 70 fathoms (record 28), and on July 7, 1923, 13 miles NE. ½ N. of Thunder Bay Island in 60 fathoms (record 32) had 20 to 47 per cent chubs. Relatively few chubs were taken on July 2, 1923, 20 miles E. by N. of the can buoy in 60 to 70 fathoms (record 30), and on July 5, 1923, 18 miles NE. ¾ E. of Thunder Bay Island in 80 to 100 fathoms (record 31).

A single lift from 50 fathoms 35 miles NE. by N. ¾ N. of Harbor Beach, Mich., on October 27, 1917 (record 33), had 50 per cent chubs. On the Ontario shore of the lake lifts were examined only in Georgian Bay. Though no chubs were collected or examined from the Duck Islands and Southampton boats, the fact that the movements of the fish caught by these boats and by the Alpena boats (as shown by their records) are similar and the fact that all three boats fish in approximately the same zone of latitude in the lake give circumstantial evidence that the lifts at the three ports can not be widely different in their components. (See Table 14 and discussion on p. 346.) In Georgian Bay, off Cape Croker, in 52 fathoms on July 28, 1919 (record 37), and on July 30, 1919, 21 miles east of Surprise Shoal in 60 fathoms (record 34), chubs made up half the catches. In a single lift made on October 6, 1919, off White Bluff in 70 fathoms (record 35), only a few chubs were taken.

In other types of netting chubs were recorded only as follows: In the trout nets lifted on September 7, 1917, 26 miles SE. by E. ¼ E. of the Alpena can buoy in 16 to 20 fathoms and in the 1½-inch nets lifted on September 8, 1917, 26 miles SE. by E. ¼ E. of that point. In both lifts chubs were rare.

All observations show the chub to range from 16 to 100 fathoms. In less than 35 fathoms it has been taken rarely. In the chub nets from 35 to 50 fathoms it is taken

in some numbers, but how abundantly the records do not show. In the chub lifts of 50 fathoms and deeper the species has been very common. In 14 of the 22 lifts made at these depths the chub made up 50 to 90 per cent of the catches, while in five lifts it comprised 20 to 47 per cent; in only three lifts was it found to be scarce. The chub population appears, therefore, to attain its greatest density at depths of 50 to 80 fathoms. The maximum depth range of the species is not indicated by the records, and it may be found even deeper than 100 fathoms.

BREEDING HABITS

The spawning grounds of the species have not yet been located in Lake Huron. Evidence from three sources establishes the time of spawning:

(1) The records of the tugs *Roy* of Alpena, *J. B. McLeod* of Southampton, and *Osprey* of the Duck Islands, given in part in Table 14, show an abrupt decline in the size of the lifts during the last week of August and during September. This decline can be explained only by assuming that this species (which, it has been shown, makes up the bulk of the chub hauls) leaves its summer feeding grounds at this time. That the fish have gone to the spawning grounds may be inferred from the facts that follow.

(2) Observations on the development of the ova of chubs at various times from the last of July to the last of October, and the finding of pearl organs on males, yield evidence of another kind. On July 28 and 30, 1919, at Wiarton and Lions Head in Georgian Bay, female chubs with well-developed ova were found. One fish, even, was ripe. On August 7, 1920, at Alpena, the females of a lift of about 3,500 pounds of chubs had nearly ripe ova. From the last of August and until the last of October examination of the ovaries revealed three conditions: (*a*) Ova in the body cavity (all ova may or may not have been liberated from the ovary); (*b*) no ova in the body cavity and only minute ova in the ovary; the ovary dark in color, still swollen, having not yet completely contracted after releasing the ova; (*c*) ova minute or at least never more than half as large as the mature ova, always large enough to give the ovary a yellow appearance; the ovary firm. Females with ovaries in the condition described under (*a*) are called spawning fish, under (*b*) spent fish, under (*c*) nonspawning fish. Of course, the ovaries of a spent female come after a time to look like those of a nonspawner, but if the fish has spawned recently, it can not be confused with one that has not spawned. Among the spawning runs of *zenithicus* and *alpenæ* no females were found that would be classed as nonspawners, while spent fish were common.

In lifts of whitefish and blackfins taken before their spawning season many nonspawning females have been seen. Out of 174 chubs examined from the catches previously referred to and made on August 30 and September 3, 1919, at Alpena, 112 were females; of these, 30 were spawning or ready to spawn, 2 were spent, and the rest nonspawning. Among 40 females examined September 21, 1917, at Alpena, 15 had a few eggs in the abdominal cavity and the rest were nonspawners. Chubs taken at Lions Head, Ontario, October 6, 1919, were spent females and males with only faint indications of pearls. These were the only pearled males seen. The large proportion of the nonspawning fish is interesting. The size of these fish ranged between 24 and 32 centimeters. As they were not different from the spawners in respect to size, it can hardly be argued that they were too small to spawn. It appears that a certain proportion of the fish spawn biennially.

(3) The third source of evidence as to the spawning season is the testimony of several fishermen who have taken spawning runs of chubs in September. Fishermen at Tobermory and Lions Head on Georgian Bay assert that many of the fish taken in their nets during the month of September off the Saugeen Peninsula in 60 fathoms on mud bottom are full of loose spawn and that at this period their lifts are often nearly doubled in weight. This would seem to indicate that a spawning run had entered the nets. *Zenithicus* is the only fish in the lake known to spawn in September, but its spawning season in Lake Huron does not begin before the middle of September and continues until the middle of October, and it is not likely, therefore, that these fish are of this species. Besides, *zenithicus* is not known to be common in Georgian Bay. *Nigripinnis* and *alpenæ* do not spawn before November, so that these species certainly are not concerned in the phenomenon described, and the spawning fish can only be chubs.

There can be no question then that the spawning period of the chub begins the last of August and continues into September: (1) The schools of fish begin to leave their feeding grounds the last of August and are absent during September. Only the nonspawning individuals and a few spawning fish remain behind. (2) Fish caught in July and early August have eggs in an advanced state of maturity. From the last of August and through September females have either only ripe or only undeveloped eggs. In October the fish taken have only undeveloped ovaries. Pearled males were taken on October 6, 1919. (3) A spawning run of fish, which must belong to this species, has been reported in Georgian Bay in September.

It remains to find the spawning grounds. If the Georgian Bay fishermen actually get the fish where they are spawning and not while they are moving to the spawning grounds, then the situation of at least one of the spawning places in Georgian Bay is established. (It is interesting to note, in this connection, that a lift examined on October 6, 1919, on these reported spawning grounds (record 35) had very few chubs in it and that these were spent.) We still have, then, the Lake Huron individuals to account for. It is not likely that the schools from the lake traverse the shallow water off Cape Hurd to get into Georgian Bay. In that case they must spawn somewhere in the lake. With no more data than are now available it is not profitable to speculate as to where these spawning grounds might be. It is better for the fish, of course, that this gap in our knowledge of their habits has not been bridged.

FOOD

Carl L. Hubbs, of the Museum of Zoology, University of Michigan, has examined a series of stomachs of coregonids collected by me on Lake Huron, and his report is given under this heading for each of the Lake Huron species. Doctor Hubbs finds, in an examination of 34 stomachs of *johannæ* collected off Alpena, Mich., in 65 to 70 fathoms in September and October, 1917, that the chief article of diet is Mysis. This animal constitutes from 80 to 100 per cent of the food in most of the stomachs. Pisidium and Pontoporeia are present in about one-third of the examinations, usually only in relatively small quantities. Half of all specimens had ingested sand, cinders, and wood fragments. Other objects casually swallowed include adult insects, larval and pupal Chironomidæ, and fish scales.

LEUCICHTHYS ALPENÆ Koelz

THE LONGJAW (FIG. 15)

Leucichthys alpenæ, Koelz, 1924, pp. 1–5; Lakes Michigan and Huron.
Argyrosomus prognathus Evermann and Smith, 1896, pp. 314–317; in part, Lakes Michigan and Huron.
Leucichthys johannæ Jordan and Evermann, 1911, pp. 24–25, in part, Lakes Michigan and Huron

The longjaw is described from Lake Michigan and is known to occur only in Huron of the other lakes of the Great Basin. In both lakes the species is characterized by the large size it may attain, its pale color, its long mandible, relatively short paired fins, and the moderate number of gill rakers on the first branchial arch. It seems to prefer moderate depths in both lakes and spawns in late November. The Huron form has been found to differ from the typical form only in having on the average somewhat fewer gill rakers and lateral-line scales and a somewhat longer head.

Type

The type is a female specimen (catalogue No. 87352, U. S. National Museum) 269 millimeters long, collected on June 15, 1923, 22 miles NNE. of Charlevoix, Mich., off Ile aux Galets in 25 to 47 fathoms.

Leucichthys alpenæ of Lake Michigan

The longjaw is the largest Leucichthys in Lake Michigan. Specimens not infrequently attain a length of 38 centimeters (15 inches) and a weight of 2 pounds. The body is compressed, fusiform, and rather elongate. The greatest depth, through a point just in front of the dorsal, comprises in adult specimens 23 to 26 per cent of the total length. Gravid females are often deeper, of course. The width is about 50 to 55 per cent of the depth. The anterior dorsal profile of the body usually rises gradually from the occiput to the insertion of the dorsal, but it is sometimes somewhat steeper over its anterior half, particularly in the largest specimens. Behind the dorsal the line continues in a very faint curve to the caudal peduncle. The ventral profile is rather strongly and uniformly curved from the tip of the snout to the caudal peduncle. There is a tendency for the contour line between the ventrals and the anal to become straight and parallel to the lateral line, however. The head, which is relatively short and deep, is contained 4.4 [(3.8) 4.1–4.4 (4.6)][18] times in the total length of the fish. In side view it is broadly triangular. The dorsal profile usually is faintly convex and forms a smooth arc continuous with that of the first half of the predorsal body contour. The degree of its convexity is greatest in those specimens in which the premaxillaries approach a vertical position. The premaxillaries may be immaculate but usually are more or less pigmented and are directed forward, ordinarily making an angle of 45° to 60° with the horizontal axis of the head. The snout, seen from the side, is broad and rounded. It is contained 3.7 [(3.3) 3.4–3.6 (4)] [19] times in the head. The maxillary is nonpigmented in about 90 per cent of over 500 specimens examined and extends beyond the anterior edge of the pupil but seldom

[18] The figures given in brackets, unless stated otherwise, are based on an examination of 289 specimens (paratypes) ranging in length from 205 to 386 millimeters.
[19] Seventy-five specimens.

to its center. The lower jaw is well developed and usually projects beyond the upper.[20] The eye is moderate in size and is contained 4.6 [(3.8) 4.2–4.6 (5.2)] times in the head length. The gill rakers on the first branchial arch number 14+25 [(11) 13–15 (17) + (20) 22–27 (30)=(33) 36–43 (46)].[21]

The scales in the lateral line number 75 [(71) 78–85 (96)].[22] Rows of scales around the body just in front of the dorsal and ventrals number 41 [(40) 41–43 (45)]; [23] just in front of the adipose and the anus 34 [(30) 33–35 (36)]; [24] around the caudal peduncle at its commencement 26 [(23) 24–26 (27)].[24] Dorsal rays number 10 [(9) 10–11)]; [25] anal rays, 11 [(9) 11–12 (13)]; [25] pectoral rays, 16 [(12) 15–17 (18)]; [25] ventral rays, 11 [(10) 11 (12)].[23] The pectorals are contained 2.2 [(1.6) 1.9–2.2 (2.5)] times into the distance from the pectorals to the ventrals. The dorsal edge of pectoral is usually nearly straight. The length of the ventrals is contained 1.8 [(1.2) 1.4–1.7 (1.9)] times in the distance from their origin to that of the anal.

The color in life is about the same as in *johannæ*. The form is also about as little pigmented, except possibly on the premaxillaries.

During the breeding season males develop pearl organs, as in the case of other Great Lakes coregonids. No individuals were taken on the spawning grounds, so that no description of the full nuptial dress can be given. Probably the full development of pearl organs is not different from that of the Lake Huron form.

VARIATIONS

Racial variations.—Most of the fish in the collection were taken in the northern part of the lake; but probably there are enough specimens from the southern part for comparison. There are no differences discernible between the two groups, however, except that those from the south appear to average still less pigmented on the premaxillaries and abdominal fins.

Size variations.—The usual changes in proportion between the large and small specimens obtain. Ten large and nine small specimens are compared extensively in Table 21. There are only 13 collected specimens less than 200 millimeters in length, and nothing can be stated definitely concerning changes with growth; but it appears that the head, eye, and paired fins are somewhat longer, relatively, in small fish. The depth and width, of course, become greater as the fish approaches maturity. I have seen no sexually mature specimens smaller than 206 millimeters.

COMPARISONS [26]

Alpenæ resembles *johannæ* most closely. The differences between the two species are discussed on page 351.

From *zenithicus*, *alpenæ* differs chiefly in the length of the mandible and maxillary, pigmentation of the premaxillaries and maxillary, depth of the head and body, and in maximum size attained. The mandible in *alpenæ* usually is longer than the

[20] In 68 per cent of 638 examined specimens.
[21] Three hundred and eighty-three specimens.
[22] Three hundred and twenty-nine specimens.
[23] Twenty specimens.
[24] Fifty specimens.
[25] Seventy-five specimens.
[26] Figures for proportions given in this section are based on specimens 200 millimeters or more in length, except *artedi*, where the limit is 225 millimeters. Counts are given for specimens of all sizes.

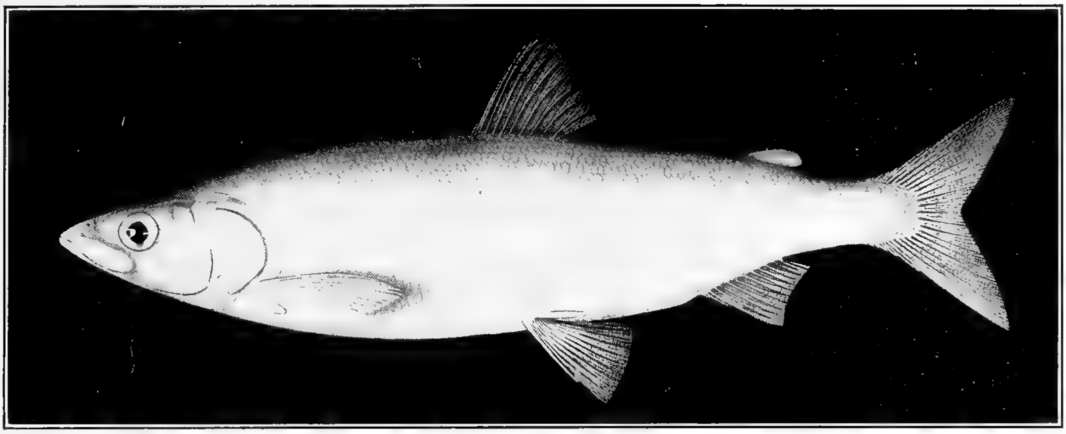

FIG. 14.—*Leucichthys johannæ* Wagner, the chub. Male, 243 millimeters long, taken in Lake Michigan off Michigan City, Ind., in 30 to 40 fathoms on September 3, 1920

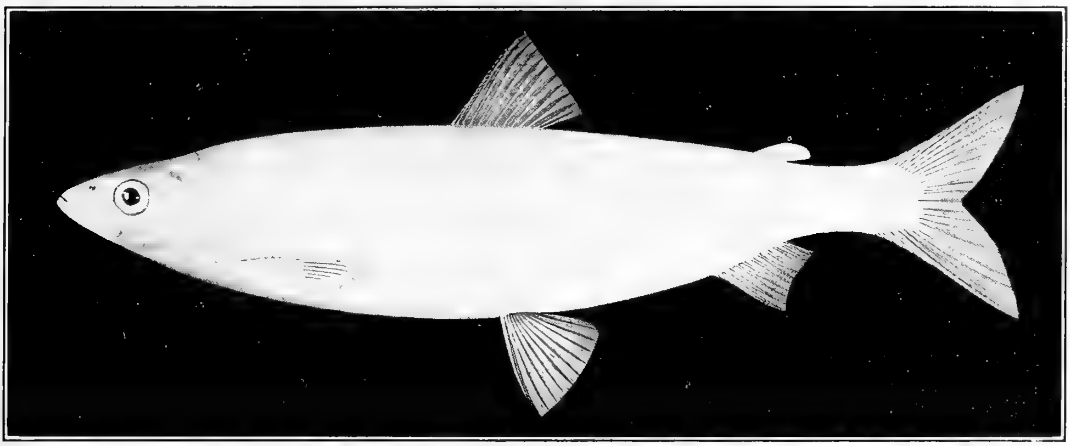

FIG. 15.—*Leucichthys alpenæ* Koelz, the longjaw. Male (type), 269 millimeters long, taken in Lake Michigan, off Charlevoix, Mich., in 25 to 47 fathoms on June 15, 1923

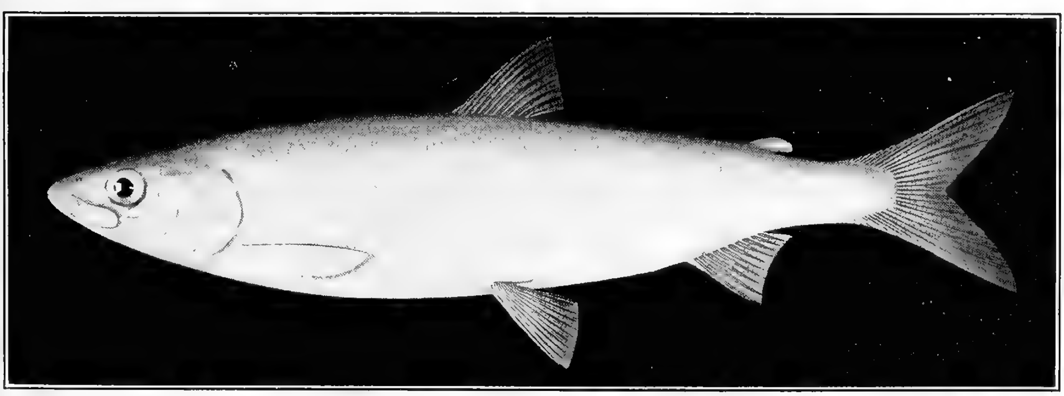

FIG. 16.—*Leucichthys zenithicus* Jordan and Evermann, the short-jawed chub. Male, 243 millimeters long, taken in Lake Superior off the Apostle Islands in 15 to 20 fathoms on July 11, 1922

upper jaw, while in *zenithicus* it is usually shorter and included within it. In the former the premaxillaries are immaculate or but faintly pigmented in half of the specimens examined and the maxillary is almost always immaculate; the premaxillaries and maxillary usually are pigmented in the latter. The depth of the head is greater and the length of the maxillary less in *alpenæ*, so that the value of the head depth (HD) divided by the maxillary length (M) is (1.4) 1.5–1.7 (1.8), with 79 per cent more than 1.5 for *alpenæ*, and (1.3) 1.4–1.6 (1.7), with 25 per cent more than 1.5 for *zenithicus*. The depth of the body in *alpenæ* is likewise more; L/D equals (3.3) 3.9–4.3 (4.9), with 11 per cent more than 4.3 in *alpenæ*, and (3.6) 4.2–4.6 (5), with 58 per cent more than 4.3 in *zenithicus*. *Zenithicus* seldom is larger than 300 millimeters, while examples of *alpenæ* that exceed this limit are met frequently. The dorsal contour of the head is straighter, also the shape of the head in side view less broadly triangular, and the body slightly wider in *zenithicus*.

Alpenæ differs from *reighardi* in about the same way that it differs from *zenithicus*—in points of pigmentation and length of mandible—but pigmentation is still more abundant in *reighardi*; and in addition to being present on the premaxillaries and maxillary it is also abundantly present on the mandible and occasionally on the abdominal fins. Moreover, *alpenæ* has more gill rakers on the first branchial arch, longer pectoral fins, a narrower body, more lateral-line scales, and attains a greater size. *Alpenæ* spawns in November while *reighardi* spawns in May or June, so that the state of ripeness of the sex products often may serve as a distinguishing character. A comparison of certain of the above-mentioned characters follows:

Gill rakers:
- *alpenæ*, (33) 36–43 (46), with 66 per cent more than 38.
- *reighardi*, (30) 34–38 (43), with 13 per cent more than 38.

Lateral-line scales:
- *alpenæ*, (71) 78–85 (96), with 47 per cent more than 81.
- *reighardi*, (66) 72–81 (96), with 12 per cent more than 81.

Pv/P:
- *alpenæ*, (1.6) 1.9–2.2 (2.5), with 9 per cent more than 2.2.
- *reighardi*, (1.7) 2–2.5 (2.8), with 41 per cent more than 2.2.

The differences between *alpenæ* and *nigripinnis* are about the same as between *nigripinnis* and *johannæ*. The difference in the number of gill rakers is not so sharp, however; while *nigripinnis* may have 41 but seldom less than 44, *alpenæ* may have 46 but seldom more than 43. In addition, *alpenæ* has shorter paired fins, a heavier and much paler mandible, and a much more elliptical body outline (as seen from the side) than *nigripinnis*. The comparative figures for fin length follow:

Pv/P:
- *alpenæ*, (1.6) 1.9–2.2 (2.5), with 89 per cent more than 1.8.
- *nigripinnis*, (1.5) 1.6–1.8 (2.2), with 18 per cent more than 1.8.

Av/V:
- *alpenæ*, (1.2) 1.4–1.7 (1.9), with 80 per cent more than 1.4.
- *nigripinnis*, 1.2–1.5 (1.6), with 28 per cent more than 1.4.

Alpenæ also spawns a month earlier than *nigripinnis*.

Alpenæ grows much larger than *kiyi*, so that only the smaller specimens are comparable with *kiyi*. The species differ chiefly in body shape, which in *alpenæ* is

wider and more fusiform, in the development of the mandible (which is much frailer in *kiyi*), in details of pigmentation, and in the length of the paired fins. The maxillaries (which usually are immaculate in *alpenæ*) are pigmented in *kiyi* as a rule, and the latter also has, on the average, more pigment on the premaxillaries, mandible, and abdominal fins than *alpenæ*. Comparative values are given:

Pv/P:
- *alpenæ*, (1.6) 1.9–2.2 (2.5), with 89 per cent more than 1.8.
- *kiyi*, (1.1) 1.4–1.7 (2.1), with 10 per cent more than 1.8.

Av/V:
- *alpenæ*, (1.2) 1.4–1.7 (1.9), with 95 per cent more than 1.3.
- *kiyi*, (0.96) 1–1.3 (1.4), with 2 per cent more than 1.3.

Alpenæ also has a smaller eye, and females of this species will show less developed ova than *kiyi* taken at the same time, as *kiyi* spawns a month earlier.

Alpenæ grows larger than *hoyi*. The mandible in *alpenæ* is heavier and less conspicuously hooked, the head is less sharply triangular (seen from the side), and the maxillary usually is immaculate, while it is always pigmented in *hoyi*. In addition, *alpenæ* has, on the average, fewer gill rakers on the first branchial arch, more lateral-line scales, a smaller eye, longer snout, and shorter paired fins than the bloater. It spawns in November, while the other spawns in March, so that the state of development of the sex organs may also be a character to separate the forms. Those characters that can be numerically expressed are compared below. The specimens of the two species are not comparable for those characters dealing with proportions, however, as the *hoyi* are smaller than the others, so that these differences, which concern proportions, are probably greater than they would be in specimens of like size.

Gill rakers on the first branchial arch:
- *alpenæ*, (33) 36–43 (46), with 24 per cent more than 41.
- *hoyi*, (37) 41–44 (48), with 71 per cent more than 41.

Lateral-line scales:
- *alpenæ*, (71) 78–85 (96), with 83 per cent more than 77.
- *hoyi*, (60) 67–77 (84), with 7 per cent more than 77.

H/E:
- *alpenæ*, (3.8) 4.2–4.6 (5.2), with 81 per cent more than 4.2.
- *hoyi*, (3.8) 3.9–4.2 (4.5), with 8 per cent more than 4.2.

H/S:
- *alpenæ*, (3.3) 3.5–3.6 (4), with 13 per cent more than 3.6.
- *hoyi*, (3.5) 3.7–3.8 (4.1), with 76 per cent more than 3.6.

Pv/P:
- *alpenæ*, (1.6) 1.9–2.2 (2.5), with 48 per cent more than 2.
- *hoyi*, (1.6) 1.8–2 (2.3), with 21 per cent more than 2.

Av/V:
- *alpenæ*, (1.2) 1.4–1.7 (1.9), with 54 per cent more than 1.5.
- *hoyi*, (1.1) 1.3–1.5 (1.7), with 9 per cent more than 1.5.

Alpenæ differs from *artedi* chiefly in having fewer gill rakers on the first branchial arch, longer ventral fins, head, snout, and maxillary. The figures for these characters for the two species are given below:

Gill rakers on the first branchial arch:
- *alpenæ*, (33) 36–43 (46), with 6 per cent more than 43.
- *artedi*, (41) 46–50 (55), with 97 per cent more than 43.

Av/V:

alpenæ, (1.2) 1.4–1.7 (1.9), witn 27 per cent more than 1.6.
artedi, (1.4) 1.6–1.8 (2.3), with 76 per cent more than 1.6.

L/H:

alpenæ, (3.8) 4.1–4.4 (4.6), with 20 per cent more than 4.3.
artedi, (4.1) 4.3–4.5 (5), with 71 per cent more than 4.3

H/M:

alpenæ, (2.4) 2.5–2.6 (2.7), with 14 per cent more than 2.6.
artedi, (2.5) 2.7–3 (3.3), with 91 per cent more than 2.6.

H/S:

alpenæ, (3.3) 3.4–3.6 (4), with 13 per cent more than 3.6.
artedi, (3.3) 3.7–4 (4.4), with 84 per cent more than 3.6.

Alpenæ is further separable from *artedi* by its less elongate body, less pigmentation on the body, especially the back and abdominal fins, its usually unpigmented maxillary, and by the well-developed and relatively long mandible. *Artedi* is a much darker fish, with much more pigmented premaxillaries, maxillary, and mandible, and a moderately developed and relatively short mandible. Both species spawn at about the same time, so the state of development of the sex organs is of no assistance in separating the species.

GEOGRAPHICAL DISTRIBUTION

My records on the occurrence of this species in Lake Michigan are given in Table 20 and are shown platted on the chart in Figure 4. There are 39 records, all but 5 of them from specimens personally recorded. From these observations it may be concluded that the longjaw is generally distributed over the lake where suitable conditions obtain. It is interesting to note that a long-jawed chub is said to have occurred in commercial quantities in the years 1892 to 1894 on the reef in the center of the lake between Port Washington and Muskegon (record 8). While it is probable that this chub was a longjaw, it can not be asserted positively.

BATHYMETRIC DISTRIBUTION

Data on the depth range of the longjaw have been collected, for the most part, from the 2⅜ to 2¾ inch nets that are set in the main lake for chubs, as a rule from 30 to 60 or even 90 fathoms, and for herring in Green Bay, where the maximum depth is 24 fathoms. However, longjaws have been taken in every kind of gill net in use and even in pounds. They have been seen from virtually all the examined chub lifts from the lake, the only exceptions being the lifts made on March 24, 1919, in 50 fathoms, and on September 24, 1920, in 22 to 25 fathoms, off Milwaukee, Wis. The former lift was made on the spawning grounds of the bloater, and it is not surprising that no longjaws were taken. The last obviously was made on poor grounds, as the total lift of all Leucichthys was but 25 pounds. In Green Bay herring alone are taken, except near the mouth of the bay, where the water is deepest; and even here herring constituted the bulk of the catches made on August 18, 1920. An occasional longjaw was taken in the lift made off Boyer Bluff on Washington Island, Wis., in 18 to 24 fathoms on that date (record 1).

In the 4½-inch nets that are set for trout in waters of 10 fathoms and deeper, longjaws were seen only on one occasion, namely, on August 11, 1920, 13 miles SE. ½ E. of Manistique, Mich., in 20 fathoms (record 38), though fishermen from

most of the ports assured me that large white herring (which probably were longjaws) formerly were gilled not infrequently in these nets. The 1½-inch bait nets that are set out of most ports at depths of 26 to 40 fathoms for the purpose of taking bait for the trout hooks take chiefly small bloaters and presumably such juvenile chubs as occur on the grounds with them. Fish were examined from these nets at seven ports (see p. 354), but no longjaws were found among the bait except at Northport, Mich., on June 23, 1920, and Traverse City, Mich., on July 18, 1923, where there were a few, and at Port Washington, Wis., on September 25, 1920, where a single specimen was obtained (records 25, 28, and 7). In the special 1½-inch nets set along the shores of Platte Bay, Mich., in 8 to 12 fathoms on July 21, 1923, and in 15 to 25 fathoms on July 23, 1923, and in Grand Traverse Bay off Lees Point, Mich., in 6 to 16 fathoms on July 25, 1923, a single specimen was taken on each date (records 21, 22, and 29).

In the pound nets set in 5 fathoms off South Manitou Island three longjaws were found on July 30, 1923 (record 23). These observations thus show that when not spawning the longjaw ranges between 5 and 90 fathoms. Whether the fish ever is taken in deeper water is not known. The statements of the fishermen who have fished for the longjaws on their spawning grounds indicate that they come abundantly into water as shallow as 10 fathoms during the spawning season.

RELATIVE ABUNDANCE

But few observations have been made on the proportion of longjaws to the other chubs. Furthermore, those for 1920 are unsatisfactory, as the fishing season for chubs was so unfavorable during that year that few fish of any kind were taken at a lift. Only the examined lifts of the chub nets mentioned in the preceding section took no longjaws. Longjaws were rare in the lifts made on November 19, 1920, 10 miles NNW. of Michigan City, Ind., in 18 fathoms; on August 18, 1920, off Washington Harbor, Wis., in 18 to 24 fathoms; on March 2, 1921, 21 miles NNW. of Michigan City, Ind., in 30 fathoms; and on March 4, 1921, 15 miles NW. by N. ½ N., in 28 fathoms; on November 15, 1920, 20 miles ESE. of Milwaukee, Wis., in 28 to 35 fathoms; on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms; on September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms; on September 23, 1920, 27 miles ESE. of Milwaukee, Wis., in 60 fathoms; on August 23, 1920, 12 miles E. by S. of the Sturgeon Bay ship-channel mouth in 60 to 70 fathoms; and on August 19, 1920, 20 miles E. ½ N. of Rock Island, Wis., in 71 to 90 fathoms (records, 16, 1, 17, 18, 10, 4, 6, 9, 3, and 2). At the north end and at one port at the south end of the lake the species was more abundant. Longjaws comprised 22 per cent of a lift made on October 4, 1920, 9 miles north of Point Betsie, Mich., in 60 to 70 fathoms (record 20). Longjaws comprised 45 to 69 per cent of a lift made on July 31, 1923, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms; on August 11, 1923, 3 miles NW. ½ W. of Charlevoix, Mich., in 35 to 60 fathoms; and on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms (records 26, 35, and 39); and 90 to 98 per cent of lifts made on June 22, 1920, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms; June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55

fathoms; August 10, 1923, 8 miles NNW. and on August 21, 1923, from an unknown locality off that port (records 24, 32, 34, and 36). At Michigan City, Ind., a lift made on September 3, 1920, 22 miles NW. by N. ½ N. in 30 to 40 fathoms, had 10 per cent (record 11); on October 11, 1920, 20 miles N. by W. ¾ W., in 30 to 40 fathoms, had 20 per cent (record 12); on November 8, 1920, 18 miles NNW. in 30 to 38 fathoms, 33 per cent (record 13); on November 19, 1920, 17 miles NNW., in 28 to 32 fathoms, 30 per cent (record 14); and 17½ miles NW. by N. ¾ N., 15 per cent longjaws (record 15). (Records 16, 17, and 18 for this port, in which few longjaws were found, were made on or near the spawning grounds of *zenithicus* and *hoyi*.)

The evidence indicates that the longjaw occurs most abundantly at the northeastern end of the lake between Frankfort, and Manistique, Mich., where the usual depth of the water is less than 70 fathoms. In this area it has been found to comprise 22 to 98 per cent of the hauls and has been taken in the 1½-inch bait nets and in the 4½-inch trout nets. A second area of abundance lies off Michigan City, Ind., at the southern end of the lake, where the water is not over 40 or 50 fathoms deep. It has been found here to comprise 10 to 33 per cent of the lifts of the chub nets. Chub lifts made at other places on the lake at depths of 18 to 90 fathoms took few longjaws, but the data are too inconclusive to determine finally the abundance of the fish there. Longjaws, according to a fisherman, formerly occurred abundantly on the reef in the center of the lake between Port Washington and Muskegon, where the chart shows a minimum depth of 38 fathoms. It appears, then, that the maximum density of the longjaw population when not spawning is between 28 and 70 fathoms only where a depth of 70 fathoms is attained in the vicinity of shallow water. Only stragglers have been found shallower or deeper.

BREEDING HABITS

No breeding fish have been seen, and the time and places of spawning are known only from inference and the testimony of fishermen. Female specimens taken on November 19, 1920, 17 miles NNW. and 17½ miles NW. by N. ¾ N. of Michigan City, Ind., showed well-developed but not ripe ova, and the males showed pearl organs. The fish certainly would spawn soon and probably in the vicinity. The fishermen say that at the north end of the lake longjaws come ashore toward the end of October and spawn during November at depths of about 10 to 25 fathoms. Known spawning grounds are situated off the east shore of Beaver Island and in Big and Little Traverse Bays (records 27, 30, 31, and 37). The bottom visited is composed of mud or clay mixed with rock, according to the fishermen. Chubs of some kind spawn off Leeland, Mich., in November at 10 to 25 fathoms, according to Walter Wilson of Northport; off Manistee, Mich., at the same time, but no shallower than 40 fathoms, according to Charles Henrickson, sr., of Charlevoix, Mich.; and off Ludington and Muskegon, Mich., at the same time in 20 fathoms, according to Will DeYoung and the Vanderberg brothers, respectively. The fishermen are unable to describe these spawning fish, and as nothing is known of the composition of the chub lifts made out of these ports during other seasons, it can not be stated that these fish are longjaws. Other spawning grounds for the species, aside from those definitely known, probably could be found.

Leucichthys alpenæ of Lake Huron

The Lake Huron longjaw closely resembles that of Lake Michigan in appearance. A comparison of the principal systematic characters is given below:

Gill rakers on the first branchial arch:
- Michigan, (33) 36–43 (46).[27]
- Huron, (31) 34–40 (44).[28]

Lateral-line scales:
- Michigan, (71) 78–85 (96).
- Huron, (70) 76–83 (91).

L/H:
- Michigan, (3.8) 4.1–4.4 (4.6).
- Huron, (3.6) 4–4.3 (4.4).

H/E:
- Michigan, (3.8) 4.2–4.6 (5.2).
- Huron, (4) 4.5–4.9 (5.2).

H/S:
- Michigan, (3.3) 3.4–3.6 (4).
- Huron, (3.1) 3.3–3.6 (3.8).

Pv/P:
- Michigan, (1.6) 1.9–2.2 (2.5).
- Huron, (1.6) 1.8–2.1 (2.3).

Av/V:
- Michigan, (1.2) 1.4–1.7 (1.9).
- Huron, (1.3) 1.4–1.7 (1.9).

It appears that Huron specimens have somewhat fewer gill rakers on the first branchial arch, fewer lateral-line scales, a somewhat larger head, and a smaller eye. The L/H ratio is the more significant that the Huron specimens average decidedly larger, and it is usual that the head is proportionally smaller on larger fish. The eye changes so markedly in comparative size with the growth of the individual that the specimens from the two lakes can not be compared satisfactorily for this character.

The color in life is as in the Lake Michigan form. Pigmentation is about as in the form of northern Lake Michigan.

Males taken on the spawning grounds in Colpoy Bay on December 3, 1919, show pearl organs. The degree of development of these pearls varies with the individual, and in the individual the development on the two sides is often unequal. In general, however, the development of the breeding adornment is about like that of *johannæ* described on page 350.

VARIATIONS

Racial variations.—The longjaw is generally distributed throughout Lake Huron and Georgian Bay, and there are probably several distinct schools in these areas. A comparison of fish from the commercial takes of Lake Huron with those of Georgian Bay, and of small fish from Lake Huron taken in less than 60 fathoms with those taken from 60 fathoms or deeper, indicates that on the basis of my material it is not possible to established any definite characteristics for any of these races.

Size variations.—Small specimens differ from large ones chiefly in proportions. Counts of gill rakers, however, show fewer rakers on the first branchial arch in small specimens. They number (31) 33–37 (41) as compared with (31) 37–40 (44) in larger specimens. The head in specimens less than 210 millimeters in length is slightly larger, contained (3.4) 3.8–4.1 (4.2) times in the total length, as compared with (3.6) 4–4.3 (4.4) for large fish. The eye is conspicuously larger in the first class. The ratios for the head divided by the eye are (3.6) 3.8–4.1 (4.4) and (4)

[27] These figures for Lake Michigan are based on an examination of 383 specimens, those for scales on 329, those for H/S on 73; all others are based on an examination of 289 specimens, ranging in length from 205 to 386 millimeters.

[28] These and succeeding figures for Lake Huron, except those for gill rakers and lateral-line scales, are given for 177 specimens, ranging in length from 210 to 368 millimeters. The figures for gill rakers are based on 417 specimens of all sizes, those for scales on 323 specimens.

4.5–4.9 (5.2). The maxillary likewise appears to decrease slightly in relative size, and the ventral fin becomes relatively shorter with increased growth. The values for H/M are (2.3) 2.4–2.6 (2.7) and (2.3) 2.5–2.6 (2.8) and for Av/V are (1.1) 1.3–1.5 (1.7) and (1.3) 1.4–1.7 (1.9) for small and large fish, respectively. The depth and width, of course, become greater as the individual approaches maturity.

Specimens of both sexes 160 millimeters long appear regularly to be approaching sexual maturity. Fish as small even as 145 millimeters have exhibited maturing sex glands.

COMPARISONS

Alpenæ resembles closely only *johannæ* and *zenithicus*. A comparison with the former is given on page 357. *Alpenæ* and *zenithicus* differ most conspicuously in the length of the mandible, the pigmentation of the maxillary, the position of the premaxillaries, and the size attained. In *alpenæ* the lower jaw usually is longer than the upper, whereas *zenithicus* usually has the lower jaw shorter than the upper and included within it, and 6 per cent of the individuals examined had pigment on the maxillary as compared with 83 per cent for *zenithicus*. The premaxillaries in *alpenæ* usually make an angle of 50° to 60° with the horizontal axis of the head, and the dorsal contour of the head usually is a smooth curve, seldom broken at the premaxillary attachment, while in *zenithicus* the angle becomes 60° to 70° and the curve of the dorsal contour of the head is broken at the symphysis with the rostral cartilage. *Zenithicus* seldom grows larger than 300 millimeters, while *alpenæ* commonly exceeds this limit. The state of development of the ova in females often will serve as a valuable character. *Alpenæ* spawns about the middle of November and *zenithicus* during the last of September and the first of October, so that the ovaries of the females of the one species usually show more mature ova than those of the other. *Alpenæ* differs from *zenithicus* in other characters, but the differences are slight. The body of *zenithicus*, as a rule, is more pigmented, the head and body shallower, the maxillary longer, and it usually has not more than 24 scale rows around the caudal peduncle at its commencement, while *alpenæ* most often has more than 24.

The longjaw and blackfin of Lake Huron differ from one another in about the same manner as the two species have been shown on page 365 to differ in Lake Michigan. However, there is another difference observable in the Lake Huron fish—namely, the size of the eye. The values for H/E are for *nigripinnis* (3.6) 3.9–4.2 (4.6), with 3 per cent more than 4.4, and for *alpenæ* (4) 4.5–4.9 (5.2), with 84 per cent more than 4.4.

Small *alpenæ* are comparable with *kiyi* and are distinguishable from them by their shorter paired fins, fewer gill rakers, smaller eye, and less pigmentation. Those characters that can be expressed numerically are compared below for all *kiyi* collected and for all *alpenæ* less than 21 centimeters in length:

Gill rakers on the first branchial arch:
- *alpenæ*, (31) 33–37 (41), with 12 per cent more than 37.
- *kiyi*, (34) 36–40 (44), with 60 per cent more than 37.

H/E:
- *alpenæ*, (3.6) 3.8–4.1 (4.4), with 78 per cent more than 3.8.
- *kiyi*, (3.3) 3.6–3.8 (4.3), with 21 per cent more than 3.8.

Pv/P:

alpenæ, (1.6) 1.8–2 (2.2), with 85 per cent more than 1.7.
kiyi, (1.1) 1.4–1.7 (1.9), with 4 per cent more than 1.7.

Av/V:

alpenæ, (1.1) 1.3–1.5 (1.7), with 93 per cent more than 1.2.
kiyi, (0.9) 1–1.2 (1.4), with 6 per cent more than 1.2.

The proportions involving the head and eye may be taken only to indicate a general trend, as of the two groups of specimens compared the *alpenæ* averaged 3 centimeters larger. The maxillary is almost always immaculate in *alpenæ* and is almost always pigmented over at least half its surface in *kiyi*. The back, also, is darker on the average in the latter. The mandible in *alpenæ* is less pigmented and more powerful than in *kiyi*, and the body shape is more elliptical as seen from the side. A discussion of the difference between *alpenæ* and *hoyi* may be found on page 461.

From *artedi*, *alpenæ* may be distinguished by the character of the mandible, which in *alpenæ* is well developed, pale, and longer, as a rule, than the upper jaw, and in *artedi* frail, more or less conspicuously pigmented, and usually shorter; by the fewer gill rakers on the first branchial arch and the longer head, snout, and maxillary. A detailed comparison of the technical characters follows:

Gill rakers on the first branchial arch: [29]

alpenæ, (31) 34–40 (44), with 16 per cent more than 39.
artedi, (40) 45–50 (53).

L/H:

alpenæ, (3.6) 4–4.3 (4.4).
artedi, (4) 4.3–4.6 (5), with 57 per cent more than 4.4.

H/M:

alpenæ, (2.3) 2.5–2.6 (2.8), with 7 per cent more than 2.6.
artedi, (2.6) 2.8–3 (3.3), with 96 per cent more than 2.6.

H/S:

alpenæ, (3.1) 3.4–3.6 (3.8), with 7 per cent more than 3.6.
artedi, (3.5) 3.7–4 (4.3), with 82 per cent more than 3.6.

Alpenæ also shows much less pigmentation, especially on the dorsal surface and on the maxillary. The latter usually is immaculate in *alpenæ* and always pigmented in *artedi*.

GEOGRAPHICAL DISTRIBUTION

In Table 22 are brought together all my data on the occurrence of the longjaw in Lake Huron. Figure 5 shows these data platted on the chart of Lake Huron.

Lake Huron proper.—With the exception of entries 5, 40, 41, 42, and 45, the 45 records for Lake Huron proper were made by me from boats entering the harbors in Michigan of Cheboygan, Rogers, Alpena, and Harbor Beach. The location in the lake from which these lifts were made is shown on the chart. (Fig. 5.) Twenty-eight of these records are from the boats that used the 2¾-inch nets suitable for chubs, and the rest are from the 4½ or 1½ inch gill nets and pound nets set for other species or from special 2¾-inch nets. Commercial fishing operations thus indicate that the longjaw is found in the deeper American waters from about the

[29] Figures for gill rakers are given for all specimens. The rest are given for specimens 210 millimeters or more in length in the case of *alpenæ*, and 225 millimeters or more in length in the case of *artedi*.

latitude of Goderich to the Straits of Mackinaw. I have not seen longjaws from the Canadian waters of Lake Huron, but A. Purvis, of the Duck Islands, tells me that he not uncommonly takes large "chubs" in 4½-inch gill nets set for trout and whitefish off the Duck Islands in the north end of the lake in 20 to 30 fathoms (record 45). His books show that the trout lifts for several years during the months of May, June, July, and August frequently took from 100 to 200 pounds of gilled chubs. The size of these fish indicates that they were longjaws. In spite of the lack of other records for the Canadian side of the international boundary, an examination of the hydrographic chart of the region shows similar physical conditions on both sides of the boundary line and leaves no doubt that the range of the longjaw extends to near the Canadian shore.

North Channel.—I have seen no longjaws from this region, but John Merrylees, of Gore Bay on Manitoulin Island, tells me that he takes large "chubs" not uncommonly in 4½-inch nets in 20 to 25 fathoms (record 46). A similar statement is made by D. Beneteau, of Thessalon (record 47). There is in the North Channel a maximum depth of 28 fathoms, shown on the chart. As neither chubs nor blackfins are known to occur in quantities in less than 50 fathoms, these Gore Bay and Thessalon fish must be either longjaws or short-jawed chubs.

Georgian Bay.—All but 2 of the 11 records for this area were made by me from the hauls of 3-inch gill nets of boats entering the ports of Lions Head and Wiarton on the eastern shore of the Saugeen Peninsula. They show that the longjaw is found in Georgian Bay in summer and fall at depths corresponding to those at which it occurs in Lake Huron. There is no reason to suppose that it does not range over the whole of Georgian Bay during this season at similar depths. Records 54 and 55 are from my own observation in late November and December, 1919, and show the fish then in shallow water in Colpoy Bay at a depth of 10 to 25 fathoms. The entire catch of the nets at this time was made up of longjaws, and all were spawners and milters. According to the statements of Stanley Boyd, of Oxenden (record 53), this spawning run was already in the bay when he put in his nets on November 19. Record 58 is from the statement of Duncan McInnis, of Meaford. It shows an inshore run of spawning fish in Owen Sound and between Meaford and Cape Rich, both south of Colpoy Bay. These data on spawning fish are discussed in another place.

From the data given in the table it may be concluded that the longjaw ranges over the whole of Lake Huron and over Georgian Bay and that it probably occurs in the North Channel also. It appears further from the records that in Georgian Bay in late November and early December there is an inshore run of spawning fish.

BATHYMETRIC DISTRIBUTION

The records so far discussed have dealt chiefly with catches taken in the chub nets at depths of 35 to 100 fathoms. I have attempted, from other evidence, to determine whether longjaws occur at depths of less than 35 fathoms. For this purpose information is available from the following sources: (1) Catches of 1½-inch gill nets set by hook fishermen off Alpena and Harbor Beach, Mich., for the purpose of taking small fish for bait; (2) catches of 4½-inch gill nets set for trout and whitefish in less than 35 fathoms at Alpena, Mich.; (3) catches of 2¾-inch gill nets set

under my direction with the trout and whitefish nets off Alpena, Mich., for the special purpose of determining the inshore range of chubs; (4) the pound nets set alongshore in shallow water.

1. *Catches of 1½-inch bait nets.*—Record 44 shows that such a net set in 31 fathoms at Harbor Beach, Mich., yielded a catch, 21 per cent of which was of small longjaws. On the other hand, lifts of identical nets in 30 fathoms off Alpena on September 8, 1917, and September 16, 1919, were examined by me without revealing more than a single specimen of this species (record 10); and in the lift made off Cheboygan, Mich., on October 15, 1919 (record 3) relatively few examples were found. The evidence from this source is scant and inconclusive and concerns only the immature fish that may be taken in gill nets of small mesh. In what quantities these small longjaws are taken in bait nets, at what seasons, and under what conditions are matters of prime interest. Record 44 shows that they made up 21 per cent of one haul, but in general it is known only that large numbers of small fish of some sort are taken daily to bait trout hooks. If a considerable percentage of these immature fish is longjaws or other species of commercial value when adult, their continued destruction may reduce greatly the supply of marketable fish of the species caught. The matter is worthy of further investigation.

2. *Lifts of 4½-inch gill nets set for trout and whitefish.*—I found large longjaws occasionally at Alpena, Mich., in September, 1917, gilled in 4½-inch trout nets lifted from 20 to 30 fathoms (record 11). Records of Alpena fishing tugs examined by me suggest that similar large fish are caught virtually throughout the season in these nets (record 40). Record 5 shows them taken daily during the last two weeks of September on rock bottom in 12 to 15 fathoms at Rogers, Mich. Record 45 shows similar fish in 20 to 30 fathoms at the Duck Islands, Ontario. Record 46 shows them during the summer off Gore Bay Lighthouse in the North Channel in 20 to 35 fathoms. Record 47 indicates that they are caught in winter at similar depths. The fish recorded under Nos. 5, 45, 46, and 47 were not seen by me, but their size indicates that they were longjaws; only the largest individuals of the species are gilled in nets of this mesh.

The specimens collected by me from 14 to 30 fathom lifts of 4½-inch trout nets at Alpena (records 9, 14, 23, 31, and 39) were small longjaws. They were not gilled in the usual sense of the word but were caught by their jaws becoming entangled in the meshes of the nets, so that their presence in the nets must be regarded as accidental. It is probable that they occur in shallow water in larger numbers than is indicated by their occasional capture in gill nets of large mesh.

3. *Lifts of 2¾-inch gill nets set in less than 30 fathoms.*—These nets were set in an attempt to determine whether gill nets of suitable mesh set on the same grounds as the 4½-inch trout nets referred to in the preceding paragraph would show longjaws in greater abundance than is indicated by their accidental capture in the trout nets themselves, or whether they occurred in localities in which the trout nets did not reveal them. The nets were lifted off Alpena as follows: September 17, 1917, 13½ miles SE. by S. of the can buoy in 15 fathoms with 4½-inch whitefish nets; September 19, 1917, 23 miles SE. by E. ½ E. of the can buoy in 30 fathoms with trout nets; September 26, 1917, 13 miles SE. by S. of the city in 17 fathoms; November 2, 1917, 7 miles E. NE. of the can buoy in 15 fathoms on honeycomb rock. In each

case a box (2,250 feet) of 2¾-inch gill nets was placed. Only 10 longjaws were taken by these nets, and all but 1 were included in the catch of September 19, 1917, in 30 fathoms (record 18). The nets set in 15 and 17 fathoms took only one longjaw on September 26, 1917 (record 26).

4. *Lifts of the pound nets.*—These ordinarily have not yielded longjaws, but relatively few ever have been examined by me. In collecting herring in Saginaw Bay, Dr. John Van Oosten has found stray longjaws on two occasions in the herring lifts made by the pound nets set in the shallow water at the bottom of the bay (records 41 and 42). The fish undoubtedly had strayed into the nets from spawning grounds somewhere along the shore.

From all the observations made by me, it appears that the depth range of the longjaw, when not spawning, is between 14 and 100 fathoms. Records 5, 45, 46, and 47, from the statements of fishermen, suggest also the occurrence of the species in shallow water, but it can not be asserted positively that the fish so reported were longjaws. In the spawning season the species appears to come into the shallowest water.

RELATIVE ABUNDANCE

Concerning the proportion of the longjaw to all the chubs in the chub lifts only the following few scattered observations, based on examination of lifts, are available: At Cheboygan, Mich., on July 21, 1917 (record 1), the longjaw was not rare in 35 to 50 fathoms. What proportion it made of the total catch is unknown. On September 28 and September 29, 1917 (record 2), it was practically absent from the lifts of the same nets. No lifts were examined at Rogers, Mich., except one made on October 14, 1917 (record 6), in 35 to 50 fathoms. This lift of about 1,500 pounds, like the lifts of September 28 and September 29 at Cheboygan, Mich., was made on the spawning grounds of *zenithicus* and contained only half a dozen longjaws. In view of the occupation of the grounds by the spawning *zenithicus*, these records show nothing conclusive concerning the occurrence of the longjaw at these depths. The hauls brought into Alpena, Mich., from depths of 60 to 80 fathoms vary in the number of the longjaws they contain. From the center of the lake, from northeast to east of the city in 1917, only an occasional longjaw was brought in on September 7, 10, 12, 14, 17, 19, 21, 24, and 26, and October 17 and 20 (records 8, 12, 13, 15, 16, 19, 21, 24, 25, 27, and 28). As these were the only catches examined from the center of the lake, it is not known whether longjaws ever occur there in numbers. Longjaws were uncommon also in the catches made from depths of 60 to 70 fathoms on August 7, 1920, 19 miles NE. ½ N. of Thunder Bay Island; in 60 to 65 fathoms in 1923 on June 28, 19 miles NE. of Thunder Bay Island, on June 30, 17 miles NE. by N. ¾ N. of Thunder Bay Island, on July 2, 20 miles E. by N. of the can buoy; and from 80 to 100 fathoms on July 5, 18 miles NE. ¾ E. of Thunder Bay Island (records 33 to 37). In three lifts made August 30 and September 3, 1919, and on July 7, 1923, 18 miles N. by E. ½ E. of Thunder Bay Island in 60 to 64 fathoms, 28 miles E. ¼ S. of the can buoy in 60 to 64 fathoms, and 13 miles NE. ½ N. of Thunder Bay Island in 60 fathoms, respectively (records 29, 30, and 38), longjaws comprised 20 to 22 per cent of the haul. A single lift examined at Harbor Beach, Mich., 35 miles NE. by N. ¾ N. from 50 fathoms on October 27, 1917 (record 43), was composed of slightly less than

half of this species. Within Georgian Bay at Wiarton and Lions Head, on July 28 and July 30, 1919, at 52 and 60 fathoms, respectively (records 51 and 48), hauls were less than half longjaws. At Lions Head on October 6, 1919, in 70 fathoms (record 49), there were few longjaws. In Colpoys Bay from November 28 to December 3, 1919, in 10 to 25 fathoms (records 54 and 55), nothing but longjaws was taken. These, which were all spawning fish, are discussed under breeding habits.

The evidence reviewed shows without doubt that the longjaw is found in varying numbers, when not spawning, at depths of 14 to 100 fathoms. Lifts made from water 60 to 80 fathoms near the center of the lake, from 60 to 100 fathoms 17 to 20 miles northerly from the mouth of Thunder Bay, and from 70 fathoms in Georgian Bay show but few individuals of the species. Those made in water of less than 50 fathoms with 2¾-inch nets show either no individuals of the species or very few. With 1½-inch nets small specimens have been taken commonly at 31 fathoms. The heavy hauls of longjaws recorded are from depths of 50 to 64 fathoms, usually near shallow-water areas. These show the species to make up 20 to 50 per cent of the total number of fish taken. Only the catches of the 4½-inch gill nets recorded by me, the use of the special 2¾-inch nets (see p. 374), and the reports of the fishermen indicate the presence of the fish in water of less than 30 fathoms outside of the spawning season. These records indicate that only small quantities of fish are taken. The records thus show that the longjaw population, except in the breeding season, has its greatest density at depths of 50 to 64 fathoms, and that the density decreases toward deeper water and toward shore until only occasional fish are taken at 100 and 14 fathoms. Certainly more data are needed to determine finally the relative density of the longjaw population at different depths.

BREEDING HABITS

Concerning the further natural history of the form little is known. That the species leaves the north end of the lake toward the last of September seems certain, as the boats from Cheboygan and Rogers take practically none at this time. (See Table 14.) Whether the cause of the disappearance is simply an inshore movement, and whether similar movements occur at the other ports of the lake, must remain unknown until facilities for further observation are available. Certainly there is an inshore movement in Georgian Bay when (during the first week of November) swarms of spawning fish enter Colpoys Bay in 10 to 24 fathoms (records 53 to 55). The fish are also said to be present at the same time in Owen Sound and between Meaford and Cape Rich in 16 to 20 fathoms (record 58). The records of stray individuals in 3 fathoms in Saginaw Bay on October 29, 1921, and on November 25, 1925 (records 41 and 42), show that some individuals come into still shallower water at this time. The bottom of the grounds then visited is broken, according to the fishermen—that is, it consists of "mud" mixed with rock and gravel. During the last week in November, 1919, I found spawn flowing freely from the females and pearl organs on the males taken in Colpoys Bay. There can be no doubt that the fish frequent these localities at this time for the purpose of depositing their eggs. In 1919 the fish were caught from November 19 to December 3 in Colpoys Bay. They left during a heavy gale the first week in December. On account of the rough

weather at this time of the year the fish are not followed after they move out of the bay.

These are the only known spawning grounds of the species, though others are certainly in existence in Lake Huron and possibly in Georgian Bay. The location of the spawning grounds in Colpoys Bay and Owen Sound and along the shore south of Cape Rich opens the way for further investigation of the life history of the longjaw. It should be practicable to secure eggs for artificial propagation, should such a step be desirable. Something could be learned about the conditions necessary for the development of the egg, also, and for the maintenance of the fry.

FOOD

Thirty stomachs were examined by Doctor Hubbs from specimens taken off Alpena, Mich., in September, 1917, in 60 fathoms and deeper. Mysis constituted the only food found in most of these stomachs. About one-third of the fish had eaten a little sand and plant remains of one kind and another. Pisidium, clay, fish scales, and cased invertebrate eggs of some kind were found in an occasional stomach. One specimen taken off Bay City, Mich., on October 29, 1921, had eaten larvæ of the May fly (Hexagenia) and some cased invertebrate eggs.

LEUCICHTHYS ZENITHICUS Jordan and Evermann

The Short-jawed Chub (Fig. 16)

Argyrosomus zenithicus Jordan and Evermann, 1909, pp. 169–171, Lake Superior, off Isle Royale.
Leucichthys zenithicus Jordan and Evermann, 1911, pp. 29–30, Lake Superior; Dymond, 1926, p. 65, Pl. VI, Lake Nipigon.
Argyrosomus hoyi Milner, 1874a, pp. 86–87, in part, Lake Superior; Evermann and Smith, 1896, pp. 310–312, pl. 22, in part, Lake Michigan.
Leucichthys hoyi Jordan and Evermann, 1911, pp. 28–29, fig. 14 and Pl. III (not V), Lake Michigan.

Leucichthys zenithicus has been described from Lake Superior and occurs also in Lakes Michigan, Huron, and Nipigon. In all four bodies of water it is represented by elongate, subterete fishes of relatively moderate size, with short, usually included mandible, relatively long snout and maxillary, shallow head, and a moderate number of gill rakers and lateral-line scales. These forms inhabit moderate depths and spawn in the fall. The Michigan and Huron races differ from the typical race in having a shorter head and pectoral fins and reduced pigmentation, especially on the maxillary. The Huron race also has somewhat fewer gill rakers. The Nipigon race has fewer gill rakers, fewer scales in the lateral line and scale rows, a relatively larger head, eye, and snout, and a slightly deeper body than the typical race. It is also paler in color and less pigmented. The Huron race spawns in September and October; the rest in October and November.

Type

The type is a male specimen (catalogue No. 62517, U. S. National Museum) 278 millimeters in length, taken "in September, 1908, in deep water off Isle Royale." Counts of certain multiple parts and proportional lengths for this specimen are shown in Table 25.

Leucichthys zenithicus of Lake Superior

The short-jawed chub does not attain great size. The largest individual I have ever seen measured only 332 millimeters, and few specimens larger than 300 millimeters have been taken. The body is moderately compressed, elongate, and, as seen from the side, tapers smoothly and regularly to the head and tail from the deepest portion of the body, which is at the front of the dorsal. The depth at this point is quite variable and ranges in adults from 19 to 27 per cent of the length, with the usual range between 21 and 24 per cent. The width is about 50 to 55 per cent of the depth. The head, which is of relatively little depth, is contained 3.7 [(3.6) 3.8–4.1 (4.4)] [30] times in the total length. The dorsal margin of the head, not including the premaxillaries, is more or less straight. The snout is long and is contained 3.5 [(3.1) 3.3–3.6 (4)] times in the head length. It is truncated in side view, due to the nearly vertical position of the premaxillaries, which usually make an angle of 60° to 70° with the horizontal axis of the head. The maxillary likewise is long, is contained 2.5 [(2.1) 2.3–2.5 (2.7)] times in the head, and except in rare cases is more or less pigmented. The lower jaw usually is immaculate or faintly pigmented and included within the upper in about three-fourths of all the specimens seen. The eye is moderate in size and is contained 4.6 [(3.9) 4.2–4.6 (5.1)] times in the head. The gill rakers on the first branchial arch number 17+28 [(13) 14–16 (17)+(21) 24–26 (29)=(32) 39–43 (46)].[31]

The scales in the lateral line number 74 [(69) 74–84 (90)].[32] Rows of scales around the body just in front of the dorsal and ventrals number 40 [(37) 39–42 (45)]; [33] just in front of the adipose and anus 34 [(31) 32–34 (35)]; [34] around the caudal peduncle 24 [(22) 23–25 (26)].[34] There are 10 [(10–11)] [35] dorsal rays, 12 [(10) 11–12 (13)] [35] anal rays, 12 [11–12] [35] ventral rays, and 16 [(15) 16–17 (18)] [35] pectoral rays. The dorsal margin of the pectorals usually is more or less straight, at least not often sharply decurved. The pectoral length divided into the pectoral-ventral distance is contained 1.6 [(1.3) 1.6–2 (2.4)] times. The length of the ventrals is contained 1.3 [(1) 1.3–1.6 (1.9)] times in the distance from their insertion to that of the anal. The sum of the greatest depth of the head and the length of the base of the anal fin divided by the sum of the snout and maxillary length $\frac{(HD+AB)}{M+S}$ equals 1.52 [(1.30) 1.45–1.55 (1.75)].

The color in life is silvery, as in the other species of Leucichthys. The color is like that described for the chub on page 349, except that the dorsal surface is dark blue green to pale pea green. The color is obscured everywhere by somewhat heavier pigmentation, which is most pronounced around the free margins of the scales. There is a distinct purplish iridescence, most intense above the lateral line and paling gradually into the colorless belly. In addition to the patches of green in the frontal bones noted in the description of the chub, there are often two streaks of

30 The figures in brackets, except where otherwise stated, are based on an examination of 787 specimens, ranging in length from 200 to 332 millimeters.

31 Eight hundred and eighty-three specimens.

32 Nine hundred and fifty-six specimens.

33 Two hundred specimens.

34 Twenty specimens.

35 Forty specimens.

green between the nares. The paired fins and often the bases of the others are faintly flesh colored. The dorsal margin and often the distal half of the rays of the pectoral, the cranial margin and a wide distal band of the dorsal and the lateral borders, the distal third of the longest and half of the shortest rays of the caudal are smoky to black in hue. Black may often be present more or less conspicuously on the ventrals and the anal, also.

All color fades after death, and after prolonged preservation the silvery tone usually disappears, leaving characters of pigmentation more conspicuous. The pigment, which in life is evident on the entire dorsal surface, is revealed in diminished abundance on the sides above the lateral line. Below the lateral line and on the cheeks pigment is scattered.

Males, at least, acquire pearl organs during the breeding season, as is indicated by the fact that a few individuals taken several weeks previous to the spawning season have traces of these excrescences. Their full development probably is not different from the development exhibited by the breeding male of Lakes Huron and Michigan.

VARIATIONS

Racial variations.—Specimens have been collected from 12 localities distributed rather uniformly along the shore of the lake. The number of specimens preserved from each port varies, for the most part, between 50 and 200, and the various collections are fairly homogeneous in respect to size. A comparison of the various locality groups shows no differences in any of the characters examined. There are indications that specimens under 200 millimeters vary according to locality and habitat. For example, those small fish that have been taken from depths of more than 60 fathoms appear to have, on the average, a slightly shorter snout and greater body depth (even making allowance for the bloating attendant on bringing the fish to the surface) than those from shallower water.

Size variations.—Rather marked variations are exhibited by the small specimens. In Table 25 are compared extensively 10 specimens of less than 200 millimeters in length and 10 specimens of more than 200 millimeters in length. In addition, there are given in Tables 8 to 11 a comparison of certain characters of all the specimens collected, which in these tables have been separated similarly according to size. The most noteworthy data are summarized below:

Gill rakers on the first branchial arch:
- Small fish, (32) 36–41 (45), with the mode at 38.
- Large fish, (34) 39–43 (46), with the mode at 40.

L/H:
- Small fish, (3.5) 3.7–4 (4.2), with the mode at 3.9.
- Large fish, (3.6) 3.8–4.1 (4.4), with the mode at 4.

H/E:
- Small fish, (3.6) 3.7–4.1 (4.5), with the mode at 3.9.
- Large fish, (3.9) 4.2–4.6 (5.1), with the mode at 4.4.

H/M:
- Small fish, (2.3) 2.4–2.6 (2.7), with the mode at 2.5.
- Large fish, (2.1) 2.3–2.5 (2.7), with the mode at 2.5.

H/S:
- Small fish, (3.1) 3.3–3.7 (3.9), with the mode at 3.5.
- Large fish, (3.1) 3.3–3.6 (4), with the mode at 3.4.

Pv/P:

Small fish, (1.4) 1.7–2 (2.4), with the mode at 2.
Large fish, (1.3) 1.6–2 (2.4), with the mode at 1.8.

Av/V:

Small fish, (1) 1.2–1.5 (1.7), with the mode at 1.4.
Large fish, (1) 1.3–1.6 (1.9), with the mode at 1.5.

On account of the smaller snout and maxillary in small specimens, the $\frac{HD+AB}{M+S}$ value averages higher in this group. It equals (1.30) 1.45–1.65 (1.75), with the mode at 1.55. For larger specimens the value is (1.30) 1.45–1.55 (1.75), with the mode at 1.50. The data summarized above and those in Table 25 indicate that the small specimens have fewer and shorter gill rakers on the first branchial arch, a larger eye, a somewhat shorter snout, maxillary, and pectorals, and a slightly larger head and longer ventrals. The depth, as is usual, is less in small individuals. Specimens 150 millimeters in length usually show maturing sex organs. Individuals less than 200 millimeters are immature occasionally, but less than 1 per cent of more than 1,000 specimens examined of greater size had undeveloped sex organs.

COMPARISONS [36]

Zenithicus resembles closely only *reighardi* and *nigripinnis*. From *reighardi* it may be distinguished by its longer snout, more gill rakers, smaller eye, shallower head, and narrower body. A comparison of such figures as can be accurately expressed in figures follows:

Gill rakers on the first branchial arch:

zenithicus, (32) 39–43 (46), with 80 per cent more than 38.
reighardi, (32) 34–38 (42), with 10 per cent more than 38.

H/E:

zenithicus, (3.9) 4.2–4.6 (5.1), with 80 per cent more than 4.2.
reighardi, (3.6) 3.9–4.2 (5), with 9 per cent more than 4.2

H/S:

zenithicus, (3.1) 3.3–3.6 (4), with 12 per cent more than 3.5.
reighardi, (3.4) 3.6–3.9 (4.1), with 93 per cent more than 3.5.

Zenithicus has, on the average, a longer maxillary, longer paired fins, and more scales in the lateral line. It has also been observed that the ovaries of *reighardi* are almost always yellowish in color, at least in September, while those of *zenithicus* are more often orange.

Zenithicus has, on the average, a longer snout and maxillary, a shorter anal base, less depth of head and body, and fewer scale rows than *nigripinnis cyanopterus*. The cumulative differences of the first four characters combined are expressed by the $\frac{HD+AB}{M+S}$ ratio, which for *zenithicus* is (1.30) 1.45–1.55 (1.75), with 14 per cent more than 1.55, and for *nigripinnis cyanopterus* (1.45) 1.65–1.75 (1.85), with 95 per cent more than 1.55. For *zenithicus* the body depth contained in the total length is (3.6) 4–4.7 (5.4), with 91 per cent more than 3.9, and for *nigripinnis* (3.2) 3.6–4.3 (4.6), with 45 per cent more than 3.9.

[36] The specimens compared in this section for proportions are those 200 or more millimeters long, except *artedi*, which are 225 or more millimeters. Counts are given for specimens of all sizes.

The total number of scale rows around the body just in front of the dorsal and ventrals is, in *zenithicus* (37) 39–42 (45), with 8 per cent more than 42, and in *nigripinnis* (40) 41–45 (47), with 51 per cent more than 40. *Zenithicus* usually shows much less pigment, especially on the tip of the mandible and on the pectorals; the dorsal margin of the pectorals is usually straight, not conspicuously decurved; and the body outline, as seen from the side, is more elliptical than in *nigripinnis*. In the latter the body is distinctly deepest in front of the dorsal, and the dorsal contour rises sharply from the occiput. The state of development of the sex organs, particularly of the ovaries, is also an aid in separating the species at certain times, as *zenithicus* spawns in November and *nigripinnis* in September.

Zenithicus attains a much greater adult size than *kiyi* and *hoyi*. Small specimens may be separated from these two species by their more elongate body shape, less body depth, more elongate head, and included mandible. Small *zenithicus* are distinguished further from *hoyi* by their fewer gill rakers on the first branchial arch, which number (32) 36–41 (45), with 17 per cent more than 40, in small *zenithicus*, and (37) 41–44 (49), with 83 per cent more than 40, in *hoyi*.

Zenithicus may be distinguished readily from *artedi* by the fewer rakers on the first branchial arch, longer snout, maxillary, head, and paired fins, and the more truncated head as seen from the side. Comparative figures for most of these characters follow.

Gill rakers on the first branchial arch:
- *zenithicus*, (32) 39–43 (46), with 4 per cent more than 43.
- *artedi*, (41) 45–48 (53), with 97 per cent more than 43.

L/H:
- *zenithicus*, (3.6) 3.8–4.1 (4.4), with 2 per cent more than 4.2.
- *artedi*, (4.1) 4.3–4.6 (5.1), with 92 per cent more than 4.2.

H/S:
- *zenithicus*, (3.1) 3.3–3.6 (4), with 12 per cent more than 3.5.
- *artedi*, (3.4) 3.6–3.9 (4.3), with 93 per cent more than 3.5.

H/M:
- *zenithicus*, (2.1) 2.3–2.5 (2.7), with 1 per cent more than 2.6.
- *artedi*, (2.5) 2.7–3 (3.1), with 92 per cent more than 2.6.

Pv/P:
- *zenithicus*, (1.3) 1.6–2 (2.4), with 14 per cent more than 1.9.
- *artedi*, (1.7) 2–2.2 (2.8), with 84 per cent more than 1.9.

Av/V:
- *zenithicus*, (1) 1.3–1.6 (1.9), with 15 per cent more than 1.5.
- *artedi*, (1.3) 1.6–1.8 (2.3), with 91 per cent more than 1.5.

GEOGRAPHICAL DISTRIBUTION

My data on the occurrence of *zenithicus* in Lake Superior are assembled in Table 24 and are platted on the chart in Figure 3. Most of the 32 records are derived from special sets of nets of 2½ and 2¾ inch mesh made by me out of various ports of the lake in the course of a survey of the Leucichthys fauna. The records are sufficiently numerous and their sources sufficiently well distributed over the lake to warrant the conclusion that *zenithicus* occurs all along the shores of Lake Superior where suitable conditions obtain.

BATHYMETRIC DISTRIBUTION

The small-meshed nets mentioned in the preceding paragraph were set either with the commercial trout nets or in gangs by themselves at depths of 11 to 100 fathoms. These nets always took *zenithicus* at every set, except the one set made in Moffat Strait on September 25, 1923, in 13 to 14 fathoms; and records 2, 3, 6, 10, 14, 15, 16, 19, 28, 29, 31, and 32 show that some specimens also became entangled in the trout nets themselves. While these data seem to indicate that the species is rather widely distributed, both vertically and horizontally, it is noteworthy that few sets were made more than 15 miles from land (see fig. 3) or, whatever their remoteness from shore, were more than a few miles from 30 or 40 fathoms shoals, from which the descent into depths of 80 fathoms or more is abrupt. It may be stated, then, that *zenithicus* ranges along the shores of Lake Superior at depths of from 11 to 100 fathoms. Whether it goes deeper is not known. It is unlikely that it often comes shallower, at least not in the fishing season, as it is unknown as an accidental inclusion among the *artedi* and *reighardi* that often are taken in the pound nets set at 4 to 10 fathoms out of various ports.

RELATIVE ABUNDANCE

The lifts of the special 2¾ and 2½ inch nets set out of the various ports are the only source of data on the relative abundance of *zenithicus* at any locality or at any depth. While the amount of netting used was relatively insignificant when the expanse of the lake is considered, yet the number of fish taken in a given period indicates in some measure their abundance along the bottom. Out of Sault Ste. Marie, Mich., a gang of 1,800 feet of netting set on June 12, 1922, 10 miles NW. by W. ¼ W. of Point Iroquois Light in Whitefish Bay, and lifted on the 14th, had about 200 fish, or 55 fish per night per 1,000 feet (record 1), of which virtually all were *zenithicus*. Out of Marquette, Mich., 6 miles NE. ¾ N., in 42 to 65 fathoms on August 8, 1921, 2,500 feet of net took about 250 fish after having been set five nights, or 20 fish per night per 1,000 feet (record 4); and the same amount of netting lifted on August 11, 18 miles NE. by N., in 100 to 80 fathoms, after seven nights out, had about 200 fish, or 11 fish per night per 1,000 feet (record 5). All but 10, or 96 per cent, of the fish taken on the 8th and all but 35, or 88 per cent, of those taken on the 11th were *zenithicus*. Out of Ontonagon, Mich., on August 24, 1921, in 2,500 feet of netting lifted 21 miles west in 15 to 45 fathoms, after having been set for seven nights, about 700 fish were taken, or 40 fish per night per 1,000 feet (record 11); and a similar gang lifted on the 25th, 6 miles NNW. in 20 to 38 fathoms, seven nights out, had about 500 fish, or 28 fish per night per 1,000 feet (record 12). Both these gangs took virtually nothing but *zenithicus*. Between Cat and South Twin Islands, of the Apostle group, 2,200 feet of net lifted on July 11, 1922, after one night out, from 15 to 20 fathoms, had about 300 *zenithicus*, or 136 fish per night per 1,000 feet (record 13), and virtually nothing else.

Three thousand feet of net lifted 20 miles NE. by E. of Duluth on July 17, 1922, in 30 to 40 fathoms, after two nights, had about 200 pounds of fish, probably 500 individuals (record 17), of which virtually all were *zenithicus*. Out of Grand Marais, Minn., in 3,500 feet of net set off Terrace Point in 30 to 65 fathoms and

lifted on September 14, 1921, after seven nights out, about 2,000 fish were taken, or 81 fish per night per 1,000 feet (record 18), of which all but a few were *zenithicus*. *Zenithicus* was rare in the 2½-inch nets set on September 15, 1923, between Silver Island and the mainland in 14 fathoms (record 20). There was a single fish among the 32 Leucichthys taken in one net (500 feet) set one night. In Thunder Bay a net lifted on September 15, 1923, off Thunder Cape in 31 fathoms, after having been set two nights, took 70 Leucichthys, or 70 fish per night per 1,000 feet of net, of which half were *zenithicus* (record 21). A net lifted north of the Welcome Islands on September 17, 1923, in 11 fathoms, after having been set two nights, took a single *zenithicus* among the 16 Leucichthys (record 22). Two nets lifted on September 17, 1923, south of the Welcome Islands in 23 fathoms, after having been set two nights, took 121 fish, or 60 fish per night per 1,000 feet of net, of which but 6 per cent were *zenithicus* (record 23). Two nets lifted on September 19, 1923, off Sawyer Bay, from 49 fathoms, two nights out, had 50 fish, or 25 fish per 1,000 feet of net per night, 62 per cent of which were *zenithicus* (record 24). On September 25, 1923, two 2½-inch nets (1,000 feet of netting) set for one night in Simpson Channel in 74 fathoms took only 4 fish, all of them *zenithicus* (record 26). On September 29, 1923, two nets lifted after four nights from 42 fathoms off Salter Island took 25 fish, or 6 fish per night per 1,000 feet of net, of which 92 per cent were *zenithicus* (record 27). One thousand feet of net set out of Rossport, Ontario, off Bread Rock in 80 to 90 fathoms, and lifted on October 4, 1921, after having been set for four nights, took about 210 fish, or 52 fish per night per 1,000 feet (record 25). All but 11 per cent of these were *zenithicus*. Two thousand five hundred feet of netting lifted on June 22, 1922, 3 miles SE. ½ E. of the Quebec Harbor Light on Michipicoten Island in 80 fathoms, three nights out, took 75 fish, or 10 fish per night per 1,000 feet (record 30), of which 60, or 79 per cent, were *zenithicus*. One thousand eight hundred feet of netting lifted off Alona Bay on the east shore of the lake on June 26, 1922, in 60 fathoms, after having been set for five nights, took about 200 fish, or 22 fish per night per 1,000 feet (record 32), of which 87 per cent were *zenithicus*. The fish taken in the 4½-inch nets in Michigan waters, out of Grand Marais (record 2), Marquette (records 3 and 6), and Ontonagon (record 10); in Wisconsin waters off South Twin Island (records 14, 15, and 16); in Minnesota waters off Grand Marais (record 19); and in Ontario waters off Port Coldwell (record 28), Michipicoten Island (record 29), and Coppermine Point (records 31 and 32), were only casual inclusions and can show little concerning the abundance of these fish.

These data indicate that *zenithicus* occurs more or less abundantly at depths of 11 to 100 fathoms, but they do not mark the zone of maximum abundance for the species because the various observations have been made at different seasons and at different places and make no allowance for seasonal migrations nor for differences of habit induced by different physical conditions. It is clear, however, that the gangs set exclusively in depths of 60 to 100 fathoms average only 17 *zenithicus* per night per 1,000 feet (records 5, 25, 26, 30, and 32), while those set wholly or in part at depths of 15 to 45 fathoms average 41 *zenithicus* (records 1, 4, 11, 12, 13, 18, 21, 23, 24, and 27). In shallower water the species has been found rare. The data indicate further that

zenithicus comprises 79 to 99 per cent of all the Leucichthys taken by the special nets, except in Thunder Bay and vicinity (records 20 to 24), where *reighardi* is commonest. *Zenithicus* does not now support, nor is it certain that it ever has maintained, a fishing industry, although at Marquette and Duluth lifts of the species are made occasionally at certain seasons. In abundance it now ranks only second to *artedi*, *nigripinnis cyanopterus* having ceased long since to occur in commercial quantities.

BREEDING HABITS

No specimens were taken in the spawning season, and the time of breeding and the location of spawning grounds are known only from the testimony of fishermen and from specimens taken out of Marquette, Mich., in December, 1922. Mr. Parker informs me that by setting 10 miles N. by W. ¼ W. in 20 to 40 fathoms during the last week in November, from 3 to 6,000 pounds of spawning chubs usually are taken in a gang of 2¾-inch nets 5 miles long lifted after four nights (record 9). The run is said to last about a week. The bottom on the spawning grounds is clay. Of the five species of "chubs" that are known from Superior, *kiyi* and *hoyi* never attain sufficient size to gill in 2¾-inch nets, *reighardi* is not known to occur east of Keweenaw Point, Mich., and *cyanopterus* spawns in September; therefore these fish can only be *zenithicus*. James Scott, of Grand Marais, Minn., gives information that indicates that the species may spawn during November along the shores near Grand Marais. He says that when the herring nets, which are floated to take *artedi*, fall by accident to the bottom, *zenithicus* are taken in them in unusual abundance. The fish are distinguished from the herring by the Grand Marais fishermen and are known locally as ciscoes.

Observations made on the state of development of the ovaries tend to confirm the above-mentioned statements. Of the specimens taken at all ports during June, July, August, and September, only a few specimens (and these were less than 200 millimeters long) collected in Whitefish Bay on June 14, 1922 (record 1), showed spawn in a state approaching ripeness. Those taken at Grand Marais, Minn., on September 14, 1921, in Thunder Bay on September 19, 1923, and at Rossport, Ontario, on October 4, 1921, had well-developed eggs, and an occasional male taken on the last two dates showed traces of pearls. The female fish taken at Marquette, Mich., in early December, 1922, were either spawning or ready to spawn.

Late November and early December is probably the spawning time for the species throughout the lake. It is likely that the small fish with ripe ova taken in June were spawning for the first time and may have retained their eggs beyond the normal time of spawning. At any rate, the proportion of specimens with such abnormal ovaries was insignificant, and there is no reason to believe that the species spawns more than once a year. The known spawning grounds at Marquette are at depths of 20 to 40 fathoms on clay, and probably it will be found that spawning grounds in other areas of the lake are similarly situated.

Leucichthys zenithicus of Lake Nipigon

Zenithicus of Lake Nipigon is compared in the chief characters with the typical race below:

Gill rakers on the first branchial arch:
  Superior, (34) 39–43 (46).[37]
  Nipigon, (33) 36–39 (42).[38]
Scales in lateral line:
  Superior, (69) 74–84 (90).
  Nipigon, (66) 70–77 (83).
L/H:
  Superior, (3.6) 3.8–4.1 (4.4).
  Nipigon, (3.5) 3.7–4 (4.2).
H/E:
  Superior, (3.9) 4.2–4.6 (5.1).
  Nipigon, (3.6) 4–4.4 (4.6).
H/M:
  Superior, (2.1) 2.3–2.5 (2.7).
  Nipigon, (2.2) 2.3–2.5 (2.8).
H/S:
  Superior, (3.1) 3.3–3.6 (4).
  Nipigon, (3) 3.2–3.5 (3.8).
Pv/P:
  Superior, (1.3) 1.6–2 (2.4).
  Nipigon, (1.5) 1.6–1.9 (2.1).
Av/V:
  Superior, (1) 1.3–1.6 (1.9).
  Nipigon, (1.1) 1.3–1.5 (1.7).
L/D:
  Superior, (3.6) 4–4.7 (5.1).
  Nipigon, (3.5) 3.7–4.5 (5).

The comparisons show that the Nipigon race differs from the typical race in having fewer gill rakers and lateral-line scales and possibly a relatively larger head, eye, and snout, and a slightly deeper body. It has also fewer scale rows.

The color in life is much paler than in the typical race. The pea green of the back is very pale, and the green cranial patches are often wanting. Pigmentation also is reduced, especially on the dorsal surface and on the maxillary, which usually is pigmented over not more than one-fourth its area, and on the abdominal fins, which are usually immaculate.

No pearled individuals have been seen, but pearl organs doubtless are developed during the breeding season.

VARIATIONS

Racial variations.—The examination of my specimens shows no indication of the occurrence of well-marked races in the lake. There are not enough specimens available for extensive comparison, however.

Size variations.—In Table 27, 10 specimens more than 200 millimeters long and 10 less than 200 millimeters long are compared extensively. The differences between the two groups are of proportion. Small specimens have a relatively larger head and eye, longer paired fins, a relatively somewhat shorter snout and maxillary, and less body depth.

Of the 14 small specimens examined, none were found sexually mature at less than 170 millimeters.

COMPARISONS [39]

Zenithicus is separable from all the species of Leucichthys of the lake except *reighardi* and *hoyi* by the number of gill rakers on the first branchial arch, which in none of the other forms number less than 44 and in *zenithicus* not more than 42.

[37] These and succeeding figures, except those for lateral-line scales, are based on an examination of 787 specimens ranging in length from 200 to 332 millimeters. Those for scales are given for 956 specimens.

[38] Figures for gill rakers and lateral-line scales are based on an examination of 160 and 147 specimens, respectively. All others are given from an examination of 141 specimens ranging in length between 200 and 308 millimeters.

[39] The specimens compared for proportions are those 200 millimeters or more in length or, in the case of *artedi*, 225 millimeters or more. The counts are given for specimens of all sizes.

Zenithicus may be separated from *reighardi* by its greater number of gill rakers and lateral-line scales, longer snout, and less depth of head and body. These characters are compared for the two species below:

Gill rakers:
- *zenithicus*, (33) 36–39 (42), with 78 per cent more than 36.
- *reighardi*, (32) 33–36 (38), with 9 per cent more than 36.

Lateral-line scales:
- *zenithicus*, (66) 70–77 (83), with 55 per cent more than 73.
- *reighardi*, (64) 66–73 (77), with 15 per cent more than 73.

H/S:
- *zenithicus*, (3) 3.2–3.4 (3.8), with 19 per cent more than 3.4.
- *reighardi*, (3.3) 3.5–3.6 (4), with 85 per cent more than 3.4.

L/HD:
- *zenithicus*, (5.8) 6.1–6.8 (7.4), with 84 per cent more than 6.2.
- *reighardi*, (5.5) 5.7–6.2 (6.6), with 10 per cent more than 6.2.

HD/S:
- *zenithicus*, (1.8) 1.9–2.1 (2.3), with 6 per cent more than 2.1.
- *reighardi*, (2) 2.2–2.3 (2.7), with 83 per cent more than 2.1.

L/D:
- *zenithicus*, (3.5) 3.7–4.5 (5), with 55 per cent more than 4.
- *reighardi*, (3.5) 3.6–4.1 (4.4), with 14 per cent more than 4.

Zenithicus has also a somewhat smaller head, a more compressed body, and shows less pigment throughout. The maxillary is usually pigmented over only one-fourth or less in *zenithicus* and at least one-third its extent in *reighardi;* and all the abdominal fins are immaculate in over two-thirds of the individuals of *zenithicus*, while two-thirds of the specimens of *reighardi* examined have some pigment.

From *nigripinnis regalis*, *zenithicus* differs, in addition to the lower gill-raker number, in having less body depth and a much more elliptical body outline as seen from the side; in having much less pigmentation on body and fins, a smaller eye, longer snout, and shorter pectorals. Certain of these characters are compared below:

L/D:
- *zenithicus*, (3.5) 3.7–4.5 (5), with 55 per cent more than 4.
- *nigripinnis*, (3.1) 3.5–4 (4.5), with 16 per cent more than 4.

H/E:
- *zenithicus*, (3.6) 4–4.4 (4.6), with 60 per cent more than 4.1.
- *nigripinnis*, (3.5) 3.7–4.1 (4.3), with 4 per cent more than 4.1.

H/S:
- *zenithicus*, (3) 3.2–3.5 (3.8), with 9 per cent more than 3.5.
- *nigripinnis*, (3.4) 3.6–3.8 (4.3), with 94 per cent more than 3.5.

Pv/P:
- *zenithicus*, (1.5) 1.6–1.9 (2.1), with 69 per cent more than 1.6.
- *nigripinnis*, (1.2) 1.4–1.6 (1.9), with 7 per cent more than 1.6.

The mandible, in relation to the upper jaw, is shorter in *zenithicus*, and the head, seen from the side, is much more elongate and less distinctly triangular.

Only small individuals can be confused with *hoyi*, as the latter does not often grow larger than 200 millimeters; and almost always they can be separated from *hoyi* by their shorter mandible (which in *hoyi*, in addition to being longer, usually has a distinct symphysial knob), less depth of head and body, and fewer gill rakers.

which in *zenithicus* number (33) 36–39 (42), with 10 per cent more than 39, as compared with (40) 42–46 (48) for *hoyi*. From the few small specimens of *zenithicus* at hand, it appears also that they have relatively smaller eyes and relatively shorter paired fins, especially ventrals.

Zenithicus is distinguishable from *artedi* and *nipigon* by having many fewer gill rakers and a longer snout and maxillary. Comparative figures follow:

Gill rakers:
- *zenithicus*, (33) 36–39 (42), with 4 per cent more than 40.
- *artedi*, (41) 46–49 (53).
- *nipigon*, (54) 56–59 (66).

H/S:
- *zenithicus*, (3) 3.2–3.4 (3.8), with 1 per cent more than 3.6.
- *artedi*, (3.5) 3.7–3.9 (4.2), with 91 per cent more than 3.6.
- *nipigon*, (3.3) 3.5–3.8 (4), with 55 per cent more than 3.6.

H/M:
- *zenithicus*, (2.2) 2.3–2.5 (2.8), with 17 per cent more than 2.5.
- *artedi*, (2.5) 2.7–2.8 (3), with 98 per cent more than 2.5.
- *nipigon*, 2.5–2.7 (3.1), with 78 per cent more than 2.5.

Zenithicus is less pigmented on body and fins and has, as a rule, a shorter and more included mandible. It is distinguished further from *nipigon* by its less depth of body and by the fact that it seldom grows longer than 300 millimeters, while specimens of *nipigon* commonly exceed that limit.

GEOGRAPHICAL DISTRIBUTION

In Table 26 are collected my data and those of the specimens examined from the University of Toronto collection on the distribution of *zenithicus* in Lake Nipigon. They are platted on the chart of the lake in Figure 2. All are derived from the use of special small-meshed nets set during the course of a survey of the fishes of the lake. The records are distributed widely enough to warrant the conclusion that *zenithicus* occurs throughout the lake where there are suitable conditions.

BATHYMETRIC DISTRIBUTION

Zenithicus was present in two of the three sets made by me in Lake Nipigon. On July 25, 1922, off the source of the Nipigon River, in 10 to 15 fathoms, *zenithicus* made up 13 per cent of the catch; and on the following day, off Macdiarmid, in 30 fathoms, 43 per cent of the take was of this species (records 16 and 1). (For a statement of the comparative abundance of the coregonids in these lifts, see p. 409.) No *zenithicus* occurred in the lift made on July 28, 1922, off Livingston Point, in 56 fathoms. The specimens from the University of Toronto collection, so far as is known, were taken at depths of 6 to 54 fathoms, but chiefly in less than 30 fathoms. The species probably prefers water of moderate depth.

BREEDING HABITS

Of five specimens collected on October 26, 1922 (record 19), one female was spent and the other individuals were nearly ripe, so that it may be assumed the spawning season falls around the first of November. Nothing else is known of the breeding behavior of the species in Lake Nipigon.

Leucichthys zenithicus of Lake Michigan

The *zenithicus* of Lake Michigan resembles closely the typical form in respect to body shape, adult size, and most systematic characters. The chief characters are compared below:

Gill rakers on the first branchial arch:
- Superior, (32) 39–43 (46).[40]
- Michigan, (35) 38–42 (44).[41]

Scales in lateral line:
- Superior, (69) 74–84 (90).[42]
- Michigan, (70) 75–85 (91).[43]

L/H:
- Superior, (3.6) 3.8–4.1 (4.4).[44]
- Michigan, (3.9) 4–4.3 (4.5).

H/E:
- Superior, (3.9) 4.2–4.6 (5.1).
- Michigan, (4) 4.2–4.5 (5).

H/M:
- Superior, (2.1) 2.3–2.5 (2.7).
- Michigan, (2.2) 2.4–2.6 (2.8).

H/S:
- Superior, (3.1) 3.3–3.6 (4).
- Michigan, (3.2) 3.4–3.7 (4).

Pv/P:
- Superior, (1.3) 1.6–2 (2.4).
- Michigan, (1.7) 2–2.2 (2.6).

Av/V:
- Superior, (1) 1.3–1.6 (1.9).
- Michigan, (1.2) 1.4–1.6 (2).

These data indicate that the Michigan form has a shorter head and pectorals than the typical form. The snout, maxillary, and ventrals may also be somewhat shorter, and the body, on the average, is somewhat wider. It is noteworthy, also, that while in Lake Superior *zenithicus* almost invariably has pigment on the maxillary, 176 out of 487, or about one-third, of the individuals examined of the form in Lake Michigan have no pigment except occasionally on the jugal. The premaxillaries in the latter class are also immaculate or but lightly pigmented, and the mandible more often is included within the upper jaw.

The color in life is not strikingly different from that of the typical form except for the reduced pigmentation. The dorsal surface and the fins are conspicuously less pigmented than in the Superior form, and of the fins the anal and ventrals are often immaculate.

Males, at least, develop pearl organs during the breeding season. The breeding dress is not known to be different from that described for *johannæ*, on page 350.

VARIATIONS

There are too few specimens from any locality to indicate whether there is local variation in this species. Small individuals of the species, however, as is usual, differ in certain characters from larger ones. In Table 29 are presented a series of counts and proportions for 7 specimens smaller than 200 millimeters, and for 10 larger than 200 millimeters. It appears from this table that the head, eye, and paired fins are somewhat larger in the small specimens and the maxillary relatively somewhat shorter.

Only one of these small specimens (a male, 192 millimeters) shows sex organs approaching maturity. Of two other small fish collected, but not recorded in the table, one male (165 millimeters) is mature.

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[40] Eight hundred and eighty-three specimens

[41] These and other figures for Lake Michigan, unless otherwise marked, are based on an examination of 123 specimens, ranging in length from 200 to 312 millimeters.

[42] Nine hundred and fifty-six specimens.

[43] One hundred and forty specimens.

[44] These and other figures for Lake Superior, unless otherwise marked, are based on an examination of 787 specimens, ranging in length from 200 to 332 millimeters.

COMPARISONS [45]

Zenithicus approaches closely only *reighardi* and *alpenæ*. It is distinguishable from typical *reighardi* by the longer snout and maxillary, smaller eye, somewhat longer head, and more gill rakers on the first branchial arch. Fish of the northern race of *reighardi*, however, usually show nearly as long a snout, and the maxillary and head differences are not so pronounced as between *zenithicus* and typical *reighardi*. A numerical expression of these characters for these fish follows:

Gill rakers on the first branchial arch:
- *zenithicus*, (35) 38–42 (44), with 74 per cent more than 38.
- *reighardi*, north, (30) 34–37 (43), with 15 per cent more than 38.
- *reighardi*, south, (31) 35–38 (43), with 13 per cent more than 38.

H/E:
- *zenithicus*, (4) 4.2–4.5 (5), with 74 per cent more than 4.2.
- *reighardi*, north, (3.7) 4–4.3 (4.6), with 16 per cent more than 4.2.
- *reighardi*, south, (3.6) 3.9–4.2 (4.4), with 5 per cent more than 4.2.

H/M:
- *zenithicus*, (2.2) 2.4–2.6 (2.8), with 23 per cent more than 2.5.
- *reighardi*, north, (2.3) 2.5–2.7 (3), with 73 per cent more than 2.5.
- *reighardi*, south, (2.5) 2.6–2.8 (2.9), with 97 per cent more than 2.5.

H/S:
- *zenithicus*, (3.2) 3.4–3.7 (4), with 30 per cent more than 3.6.
- *reighardi*, north, (3.2) 3.4–3.8 (4.3), with 40 per cent more than 3.6.
- *reighardi*, south, (3.5) 3.6–4 (4.4), with 83 per cent more than 3.6.

MS/E:
- *zenithicus*, (2.6) 2.8–3.1 (3.2), with 97 per cent more than 2.6.
- *reighardi*, north, (2.2) 2.5–2.7 (3.1), with 46 per cent more than 2.6.
- *reighardi*, south, (2.2) 2.4–2.6 (2.8), with 5 per cent more than 2.6.

L/H:
- *zenithicus*, (3.9) 4–4.3 (4.5), with 7 per cent more than 4.3.
- *reighardi*, north, (3.9) 4.1–4.4 (4.7), with 26 per cent more than 4.3.
- *reighardi*, south, (4) 4.2–4.5 (4.8), with 48 per cent more than 4.3.

Reighardi has a wider body, deeper head, shorter pectorals, and more heavily pigmented premaxillaries, maxillary, and mandible, and there is often more pigment on the body and abdominal fins. (See also fig. 11.)

Discussion of the differences between *zenithicus* and *johannæ* and *alpenæ* are given on pages 351 and 364.

Zenithicus is easily distinguished from *nigripinnis* by the fewer gill rakers, which in the former are not more than 44 and in the latter seldom less; by its shallower and more elongated head in side view, as contrasted with the deep, blunt one of *nigripinnis;* by its less body depth, which in side view is usually elliptical in the first and ovate in the other; by the mandible, which in *zenithicus* is not conspicuously pigmented and is included in the upper jaw and in *nigripinnis* is usually heavily pigmented and equal to or longer than the upper jaw; and by the much paler and shorter paired fins. The comparative figures for fin length follow:

Pv/P:
- *zenithicus*, (1.7) 2–2.2 (2.6), with 90 per cent more than 1.8.
- *nigripinnis*, (1.5) 1.6–1.8 (2.2), with 18 per cent more than 1.8.

Av/V:
- *zenithicus*, (1.2) 1.4–1.6 (2), with 64 per cent more than 1.4.
- *nigripinnis*, 1.2–1.5 (1.6), with 28 per cent more than 1.4.

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[45] Figures given under this section for proportions are based on specimens 200 millimeters or more in length, except *artedi* where the limit is 225 millimeters. Counts are given for specimens of all sizes.

Zenithicus spawns in November and *nigripinnis* spawns in late December and early January, so that the state of ripeness of the sex products may aid also in separating certain specimens.

Zenithicus differs from *kiyi* chiefly in the length of the mandible and paired fins, size of the eye, and body shape. In *zenithicus* the mandible is heavy, never with a symphysial knob, and usually shorter than the upper jaw; in *kiyi* the mandible is frail, usually with a symphysial knob, and equals or exceeds in length the upper jaw.

Zenithicus has a smaller eye and much shorter paired fins than *kiyi* and, moreover, attains greater size. Extreme examples of the former measure 312 millimeters; of the latter, 245 millimeters. The eye, of course, changes in proportion to the head with growth, and while the specimens of *zenithicus* average larger than the kiyis, they were all taken in the same nets, and the differences thus are those that would be exhibited by specimens in the same catch. The figures are given:

H/E:
- *zenithicus*, (4) 4.2–4.5 (5), with 93 per cent more than 4.1.
- *kiyi*, (3.6) 3.8–4.2 (4.3), with 19 per cent more than 4.1.

Pv/P:
- *zenithicus*, (1.7) 2–2.2 (2.6), with 97 per cent more than 1.7.
- *kiyi*, (1.1) 1.4–1.7 (2.1), with 18 per cent more than 1.7.

Av/V:
- *zenithicus*, (1.2) 1.4–1.6 (2), with 90 per cent more than 1.3.
- *kiyi*, (0.96) 1–1.3 (1.4), with 2 per cent more than 1.3.

The body of *zenithicus* is much wider and less deep, and the slope of the body contours as seen from the side is more gradual than in *kiyi*. The shape of the head, seen from the side, is also different because of the difference in position of the premaxillaries in the two forms. *Zenithicus* shows, on the average, less pigment on the head, back, and fins. Female *kiyi* will show ova in a more advanced state of development than females of *zenithicus* taken at the same time, as *kiyi* probably spawns a month earlier.

Zenithicus may be distinguished readily from *hoyi* by its shorter and heavier mandible and shallower and more elongate head and body. The snout, also, is more truncate, due to the more vertical position of the premaxillaries. In *hoyi* the mandible is frail, usually with a symphysial knob, and equals or exceeds in length the upper jaw.

The head is distinctly triangular in side view, and the body is always conspicuously deep, the depth often due to bloating. *Hoyi*, moreover, is a decidedly small species. Few individuals grow larger than 230 millimeters, while *zenithicus* attains a length of 300 millimeters. Numerous small specimens of *hoyi* usually are found ensnarled in the twine of all the commercial nets of whatever mesh, while small *zenithicus* seldom are taken in this manner. *Zenithicus* has fewer gill rakers on the first branchial arch, more lateral-line scales, a smaller eye, longer snout, and shorter paired fins. Those characters that can be expressed numerically are compared below. The specimens of the two species, however, are not comparable for those characters that deal with proportions, inasmuch as the *hoyi* are smaller than the others, so that these differences probably are greater than they would be in specimens of like size.

Gill rakers on the first branchial arch:
- *zenithicus*, (35) 38–42 (44), with 19 per cent more than 41.
- *hoyi*, (37) 41–44 (48), with 71 per cent more than 41.

Lateral-line scales:
- *zenithicus*, (70) 75–85 (91), with 73 per cent more than 76.
- *hoyi*, (60) 67–77 (84), with 11 per cent more than 76.

H/E:
- *zenithicus*, (4) 4.2–4.5 (5), with 74 per cent more than 4.2.
- *hoyi*, (3.8) 3.9–4.2 (4.5), with 8 per cent more than 4.2.

H/S:
- *zenithicus*, (3.2) 3.4–3.7 (4), with 30 per cent more than 3.6.
- *hoyi*, (3.5) 3.7–3.8 (4.1), with 76 per cent more than 3.6.

Pv/P:
- *zenithicus*, (1.7) 2–2.2 (2.6), with 55 per cent more than 2.
- *hoyi*, (1.6) 1.8–2 (2.3), with 21 per cent more than 2.

Av/V:
- *zenithicus*, (1.2) 1.4–1.6 (2), with 41 per cent more than 1.5.
- *hoyi*, (1.1) 1.3–1.5 (1.7), with 9 per cent more than 1.5.

Females of the species may be distinguished further by the difference exhibited in the state of development of ova. *Zenithicus* spawns in November and *hoyi* in March.

Zenithicus differs from *artedi* chiefly in having fewer gill rakers on the first branchial arch, longer ventral fins, head, snout, and maxillary. The figures for these characters for the two species are given below:

Gill rakers on the first branchial arch:
- *zenithicus*, (35) 38–42 (44), with 3 per cent more than 43.
- *artedi*, (41) 46–50 (55), with 97 per cent more than 43.

Av/V:
- *zenithicus*, (1.2) 1.4–1.6 (2), with 12 per cent more than 1.6.
- *artedi*, (1.4) 1.6–1.8 (2.3), with 76 per cent more than 1.6.

L/H:
- *zenithicus*, (3.9) 4–4.3 (4.5), with 7 per cent more than 4.3.
- *artedi*, (4.1) 4.3–4.5 (5), with 71 per cent more than 4.3.

H/M:
- *zenithicus*, (2.2) 2.4–2.6 (2.8), with 9 per cent more than 2.6.
- *artedi*, (2.5) 2.7–3 (3.3), with 91 per cent more than 2.6.

H/S:
- *zenithicus*, (3.2) 3.4–3.7 (4), with 30 per cent more than 3.6.
- *artedi*, (3.3) 3.7–4 (4.4), with 84 per cent more than 3.6.

Zenithicus is less pigmented and paler in color on the back and cranium and on the abdominal fins than *artedi*; and the mandible, while not much shorter than in the latter, is heavier and less pigmented. Both species spawn at about the same time, so the state of development of the sex organs is of no systematic importance.

GEOGRAPHICAL DISTRIBUTION

My data on the occurrence of *zenithicus* in Lake Michigan are given in Table 28 and are platted on the chart in Figure 4. There are 27 records, all but 2 of them made from an examination of the catches of the commercial chub nets set out of 12 ports on the lake. The records show that the species is found along the shores of the lake, except in Green Bay, and in the strip of the Michigan shore between Frankfort and

94995—29——7

Grand Haven. However, no satisfactory investigations have been made in the latter area, and it is not unlikely that *zenithicus* occurs there also. It may be stated, then, that *zenithicus* may be found in suitable conditions throughout Lake Michigan.

BATHYMETRIC DISTRIBUTION

The records in Table 28 are made chiefly from the 2½ to 2¾ inch chub nets, which were set during the fishing season in between 12 and 90 fathoms. All the lifts of these nets took at least a few short-jawed chubs, except three lifts in Green Bay (two on August 16, 1920, off Little Sturgeon and 8 miles south of Green Island in 11 and 16 fathoms, respectively, and the other on August 18, 1920, 4 miles west of Boyer Bluff in 18 to 24 fathoms), the lift made 5 miles northwest of Cathead Light, Mich., on June 22, 1920, in 40 to 60 fathoms, and the three lifts made off Charlevoix, Mich., on August 10, 11, and 21, 1923, in 35 to 60 fathoms. It is to be noted that the observations out of Milwaukee, Wis., and Michigan City, Ind., which show the fish in the shallowest water, were made on or near the spawning grounds of the species and during the breeding season.

No specimens have been seen among the small fish casually taken by the 4 to 4½ inch trout and whitefish nets; and in the catches of the 1½-inch bait nets set in 26 to 40 fathoms, examined at seven ports (see p. 354), only a few individuals were seen at Sheboygan, Wis., on September 28, 1920, and at Port Washington, Wis., on September 25, 1920.

The data at hand from the commercial chub nets warrant the conclusion that *zenithicus* in Lake Michigan during the year ranges between the depths of 12 and 90 fathoms. It probably does not come into shallower water, at least not during the summer, as none ever have been reported from the herring pound nets that are set out of several ports at depths of less than 10 fathoms. The juvenile individuals, it appears, are not common during the summer at 26 to 40 fathoms, as they were seen seldom in the 1½-inch bait nets.

RELATIVE ABUNDANCE

Only the seven lifts of the commercial small-meshed nets mentioned in the preceding paragraph took no *zenithicus*. Lifts of the chub nets in which only an occasional specimen occurred were made out of Washington Harbor, Wis., on August 19, 1920, 20 miles E. ½ N. of Rock Island, in 71 to 90 fathoms (record 1); off Sturgeon Bay, Wis., on August 23, 1920, 12 miles E. by S. of the ship-channel mouth, in 60 to 70 fathoms (record 2); on September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms (record 6); on March 2 and 4, 1921, 21 miles NNW. and 15 miles NW. by N. ½ N. of Michigan City, Ind., in 28 to 30 fathoms (records 20 and 21); on October 4, 1920, 9 miles north of Point Betsie, Mich., in 60 to 70 fathoms (record 24); on July 31, 1923, 5 miles northwest of Cathead Light in 40 to 60 fathoms (record 25); and on June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55 fathoms (record 26). All these lifts were made outside the spawning season of the species. Only four other lifts were examined previous to October 11, and in these the percentage of *zenithicus* ranged from 20 to 40. A lift of 310 pounds, made on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms (record 3), had 20 per cent *zenithicus;* a lift of 250 pounds, made on September 23, 1920, 27

miles ESE. of Milwaukee, Wis., in 60 fathoms (record 10), had 35 per cent; a lift of unknown size, made on September 3, 1920, 22 miles NW. by N. ½ N. of Michigan City, Ind., in 30 to 40 fathoms, had 29 per cent (record 14); and a lift of 200 pounds, made on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms, had 40 per cent (record 27).

The remaining records were made out of Milwaukee, Wis., and Michigan City, Ind., during October and November, either near or on the spawning grounds of the species and in or approximately in the breeding season. On November 15, 1920, a lift of 700 pounds, made 20 miles ESE. of Milwaukee, Wis., in 28 to 35 fathoms, was composed almost exclusively of *zenithicus* (record 12). Off Michigan City, Ind., a lift of 535 pounds, made on October 11, 1920, 20 miles N. by W. ¾ W., in 30 to 40 fathoms, had 44 per cent *zenithicus;* a lift of 1,000 pounds, made on November 8, 1920, 18 miles NNW., in 30 to 38 fathoms, had 54 per cent; a lift of 700 pounds, made on November 19, 1920, 17 miles NNW., in 28 to 32 fathoms, had 15 per cent; a lift of undetermined size, made on November 19, 1920, 10 miles NNW., in 18 fathoms, had 93 per cent; and a lift made on November 19, 1920, 17½ miles NW. by N. ¾ N., in 32 fathoms, had 70 per cent (records 15 to 19).

The records show nothing clearly about the zone of maximum density for the species. Previous to the spawning season it has been found rare in three lifts at 60 fathoms and deeper (records 1, 2, and 24) and to comprise 35 and 40 per cent of two lifts at similar depths (records 10 and 27). In seven lifts at 40 to 65 fathoms it was rare or absent (records 6, 25, and 26, Northport and Charlevoix), and in two others at 30 to 50 fathoms made up 20 and 29 per cent of the lifts (records 3 and 14). (Green Bay records that show chiefly or exclusively *artedi* and records 20 and 21, made on March 2 and 4, 1921, in 28 to 30 fathoms on the spawning grounds of *hoyi*, are excepted.) In this connection, it should be pointed out that the records of few short-jawed chubs were made (excepting record 6) in the northern part of the lake, and it is possible that the species is not widely distributed in that section. In the breeding season lifts made between 18 and 40 fathoms in the southern part of the lake had 15 to 99 per cent of *zenithicus*, the density varying, it is supposed, with the proximity of the nets to the spawning grounds (records 12, 15 to 19.) As the fishermen have learned from experience to conduct their fishing operations for deep-water Leucichthys largely in 60 fathoms or less, it is probable that *zenithicus* finds its maximum density when not spawning outside the 60-fathom contour.

BREEDING HABITS

Fish have been taken on their spawning grounds off Milwaukee, Wis., and Michigan City, Ind. Fishermen report a chub spawning off Port Washington, Wis., and Grand Haven, Mich., which from their description appears to be of this species. Doubtless there are breeding grounds in the entire area between Port Washington and Grand Haven and possibly off other ports on the lake. A chub of some sort is said to spawn out of Algoma and Sheboygan, Wis., and Ludington, Mich., but it is not certain from the description of these fish that they are *zenithicus*. On all grounds spawning takes place on sand and clay at depths of 10 to 30 fathoms, according to the fishermen, the depth varying with the weather. When the lake is calm the fish come shal-

lowest, and the fishermen move their nets in and out to follow them. The time of spawning is said also to be affected by climatic conditions and regularly varies about two weeks. The fish, as a rule, congregate between the middle of October and the first of November and remain on the grounds about a month. In 1920 spawning was later than usual. Out of Milwaukee, on November 15 in 28 to 35 fathoms (record 12), and out of Michigan City, Ind., on November 19 in 18 and 28 to 32 fathoms (records 18 and 19), virtually all the females were still hard. The males were pearled and exuded milt on pressure. It is noteworthy that the lift on November 19 in 18 fathoms had 93 per cent *zenithicus*, while the lift made in 28 to 32 fathoms 7 miles farther out on the same course had only 15 per cent. Furthermore, 87 per cent of the fish recorded under record 18 were males, and about the same percentage of the fish recorded under record 12 were females. These observations may indicate that the males may move first to the spawning grounds in shallow water, as is known to be the case in some other coregonids.

Leucichthys zenithicus of Lake Huron

Zenithicus in Lake Huron likewise seldom grows larger than 300 millimeters, and as nets of 2¾-inch mesh are the smallest used for chubs it is one of the smallest of the chubs commonly taken. In body shape and most other systematic characters the form of Lake Huron closely resembles the typical form. The body, however, is wider on the average. The chief systematic characters are compared in detail in Tables 6 to 11, and are summarized below:

Gill rakers on the first branchial arch:
- Superior, (32) 39–43 (46).[46]
- Huron, (34) 37–40 (44).[47]

Lateral-line scales:
- Superior, (69) 74–84 (90).
- Huron, (70) 72–82 (88).

L/H:
- Superior, (3.6) 3.8–4.1 (4.4).
- Huron, (3.9) 4.1–4.3 (4.5).

H/E:
- Superior, (3.9) 4.2–4.6 (5.1).
- Huron, (3.9) 4.2–4.6 (5.2).

H/M:
- Superior, (2.1) 2.3–2.5 (2.7).
- Huron, (2.3) 2.4–2.6 (2.7).

H/S:
- Superior, (3.1) 3.3–3.6 (4).
- Huron, (3.2) 3.4–3.7 (4).

Pv/P:
- Superior, (1.3) 1.6–2 (2.4).
- Huron, (1.6) 1.9–2.1 (2.3).

Av/V:
- Superior, (1) 1.3–1.6 (1.9).
- Huron, (1.2) 1.5–1.6 (1.8).

These data indicate that the Huron form has, on the average, slightly fewer gill rakers on the first branchial arch, a shorter head, and perhaps a somewhat shorter snout, maxillary, and paired fins than the typical form. Furthermore, while in Lake Superior *zenithicus* almost always has pigment on the maxillary, 19 out of 116 individuals examined have no pigment on the maxillary but a little on the jugal. The mandible also is less often equal to or longer than the upper jaw. The Michigan form differs from the typical form in virtually the same characters, and the variation is in the same direction.

The color of living specimens is not different from that of the typical form. Preserved specimens from which all color has vanished show less pigment on the pec-

[46] Figures for Lake Superior for gill rakers are given for 883 specimens, those for scales for 956. All others are given for 787 specimens, ranging in length from 200 to 332 millimeters.

[47] These and other figures for Lake Huron, except those for lateral-line scales, which are given for 166 specimens, are based on an examination of 91 specimens 200 to 318 millimeters in length.

torals and anal, and the ventrals are usually immaculate. The maxillary is also sometimes unpigmented.

Males taken on the breeding grounds off Cheboygan and Rogers, Mich., during the last half of September and the first half of October show pearl organs, which are distributed on the scales as in the Lake Michigan specimens and differ from them in their development only in being smaller. It is possible, however, that the individuals examined have not attained their full nuptial dress.

VARIATIONS

Virtually all specimens of the species obtained have come from the same locality so that there are no data on local variation. Small individuals, however, differ in certain respects from large ones. In Table 31, 10 specimens of less than 200 millimeters and 10 specimens larger are compared extensively, and in Tables 8 to 11 are given the variations of some of the principal characters for all collected specimens of either class. A résumé is given below:

Gill rakers on the first branchial arch:
- Large specimens, (34) 37–40 (44).
- Small specimens, (32) 35–38 (41).

L/H:
- Large specimens, (3.9) 4.1–4.3 (4.5).
- Small specimens, (3.7) 4–4.2 (4.4).

H/E:
- Large specimens, (3.9) 4.2–4.6 (5.2).
- Small specimens, (3.5) 3.7–4.1 (4.3).

H/M:
- Large specimens, (2.3) 2.4–2.6 (2.7).
- Small specimens, (2.2) 2.5–2.7 (2.9).

H/S:
- Large specimens, (3.2) 3.4–3.7 (4).
- Small specimens, (3.2) 3.5–3.8 (4.3).

Pv/P:
- Large specimens, (1.6) 1.9–2.1 (2.3).
- Small specimens, (1.7) 2–2.2 (2.6).

Av/V:
- Large specimens, (1.2) 1.5–1.6 (1.8).
- Small specimens, (1.1) 1.3–1.6 (1.7).

The data indicate that smaller individuals have fewer gill rakers, a somewhat longer head, a larger eye, a somewhat shorter snout, maxillary, and pectorals, but somewhat longer ventrals. The small fish, however, are chiefly from a locality different from that which yielded the larger ones and may belong to another race. The body depth is also less, of course.

The smallest collected specimens (139 millimeters) were sexually mature, but some immature individuals were found as long as 215 millimeters.

COMPARISONS

Zenithicus resembles most closely *alpenæ.* A discussion of the differences between these two species may be found on page 371. *Zenithicus* is compared with *johannæ* on page 357.

Zenithicus is distinguished from *nigripinnis* by its paler fins (which in *nigripinnis* are often very black), more fusiform and shallower body, more elongate and narrower head, more included mandible, and by the fewer gill rakers, which number (34) 37–40 (44),[48] with 2 per cent more than 41, as compared with (40) 46–50 (52), with 97 per cent more than 41 in *nigripinnis.* Females of the two species can be distinguished, likewise, by the degree of development of their ova, for *zenithicus* spawns prior to the middle of October and *nigripinnis* after November.

[48] Figures in this paragraph are given for specimens 200 millimeters or more in length.

Only small *zenithicus* can be confused with *kiyi* as examples of the latter of greater size than 249 millimeters have not been seen. Small *zenithicus* may be distinguished from *kiyi* by their included mandible, which is usually longer than the upper jaw and with a symphysial knob in *kiyi*; by their more fusiform body, their smaller, less triangular head, which in *zenithicus* of less than 200 millimeters in length is contained (3.7) 4–4.2 (4.4) times in the head length, with 85 per cent more than 3.9, as compared with (3.5) 3.6–3.9 (4.1) times, with 6 per cent more than 3.9 for *kiyi;* and their shorter paired fins, especially the pectorals. The value of Pv/P for small *zenithicus* is (1.7) 2–2.2 (2.6), with 97 per cent more than 1.7, and for *kiyi* (1.1) 1.4–1.7 (1.9), with 5 per cent more than 1.7. The eye, compared with the head length, is also smaller in *zenithicus*.

For a discussion of the distinctions between *zenithicus* and *hoyi*, see page 461.

From *artedi*, *zenithicus* may be separated by its fewer gill rakers, longer head, snout, and maxillary. These characters for the two species are compared below:[49]

Gill rakers:
- *zenithicus*, (34) 37–40 (44), with 49 per cent more than 39.
- *artedi*, (40) 45–50 (53).

L/H:
- *zenithicus*, (3.9) 4.1–4.3 (4.5), with 1 per cent more than 4.4.
- *artedi*, (4) 4.3–4.6 (5), with 57 per cent more than 4.4.

H/M:
- *zenithicus*, (2.3) 2.4–2.6 (2.7), with 3 per cent more than 2.6.
- *artedi*, (2.6) 2.8–3 (3.3), with 96 per cent more than 2.6.

H/S:
- *zenithicus*, (3.2) 3.4–3.7 (4), with 29 per cent more than 3.6.
- *artedi*, (3.5) 3.7–4 (4.3), with 82 per cent more than 3.6.

Zenithicus averages also fewer scales in the lateral line and longer paired fins, and the mandible is better developed and more decidedly included within the upper jaw. *Zenithicus* spawns in late September and *artedi* spawns in November, so that the state of development of the sex organs, especially in females, also serves as a character to separate the two species.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of this species in Lake Huron are assembled in Table 30 and are platted in Figure 5. It is noteworthy that there are fewer records for the short-jawed chub from the 2¾-inch nets than for the longjaw or chub, but that, on the other hand, there are many more records for it from the 4½-inch nets.

Lake Huron proper.—Though the short-jawed chub has not always been found in the lifts of the 2¾-inch chub nets, the locations from which it has been taken in general are not different from those that have yielded longjaws and chubs, and thus the same conclusions on distribution are warranted for this form as for these other fish. It may be stated, then, at least provisionally, that the species ranges throughout Lake Huron in water of 14 to 100 fathoms.

North Channel.—No specimens have been seen from the North Channel. Chubs of some sort, however, are known to occur in the region (see p. 373). The chart shows

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[49] Figures for *zenithicus* are based on fish 200 millimeters or more in length; for *artedi* on specimens 225 millimeters or more in length, except in the case of gill rakers, which are given for all the specimens collected. The figures of the *manitoulinus* race are not included.

a maximum depth of 28 fathoms for the channel, and as this species has been taken in water as shallow it is possible that it may be present here.

Georgian Bay.—From Georgian Bay a gilled specimen was found among the chubs taken on November 6, 1917, off Wiarton, Ontario, in 45 to 60 fathoms; and on July 30, 1919, out of Lions Head, Ontario, in 60 fathoms two small individuals were found ensnarled in the netting. Though no specimens have been seen among the samples taken from five other lifts, not including those made on the spawning grounds of the longjaw, it is possible, nevertheless, that *zenithicus* occurs throughout the bay and that the nets are not set in the proper locations or possibly are of too large mesh to capture it.

From these data it appears that *zenithicus* probably is found throughout Lake Huron proper and possibly throughout Georgian Bay at depths of 14 to 100 fathoms, but that it has not yet been recorded from the North Channel.

BATHYMETRIC DISTRIBUTION

The table shows *zenithicus* to have been taken in the 2¾ and 3 inch chub nets at depths of 35 to 100 fathoms. In less than 35 fathoms its occurrence has been established only by means of the 4½-inch trout nets, the 2¾-inch chub nets that were set under my direction with the trout gangs, and the 1½-inch bait nets. The 4½-inch nets brought in specimens in 1917 on September 7, 10 (two boats), 12, 14, and 22, and on July 10, 1923 (records 9, 11, 12, 13, 14, 22, and 35). The box of 2¾-inch nets set with the 4½-inch gangs off Alpena, Mich., on September 17, 1917, 13½ miles SE. by S. of the can buoy in 15 fathoms (record 16); on September 19, 1917, 23 miles SE. by E. ½ E. of the can buoy in 30 fathoms (record 19); and on September 26, 1917, 13 miles SE. by S. of the city in 17 fathoms (record 23) brought in *zenithicus*. However, none were caught in the box of nets lifted on November 2, 1917, 7 miles ENE. of the can buoy in 15 fathoms. The 1½-inch bait nets in about 30 fathoms took specimens at Cheboygan, Mich., on October 15, 1919 (record 4), at Alpena, Mich., on September 8, 1917, and September 16, 1919 (records 10 and 29), and at Harbor Beach, Mich., on March 15, 1919 (record 37). From these data it appears that at least during late summer and early fall *zenithicus* ranges at depths of 14 to 100 fathoms in Lake Huron.

RELATIVE ABUNDANCE

The short-jawed chub has been seen in large quantities in the chub nets only on its spawning grounds in 35 to 50 fathoms northward from Forty Mile Point from the middle of September to the middle of October (records 2, 3, and 6). On or near the same grounds it occurs in some numbers outside the spawning season (records 1 and 5), but how abundant it is then is not known.

Out of Alpena, Mich., *zenithicus* always has been rare or absent in the 11 lifts examined, made in September and October, 1917, in the center of the lake northeast or east of the city in 60 to 80 fathoms (records 7, 8, 15, 17, 24, and 25), and in the five examined lifts made nearer shore in 60 to 100 fathoms on August 7, 1920, 19 miles NE. ½ N. of Thunder Bay Island, June 28, 1923, 19 miles northeast of Thunder Bay Island, June 30, 1923, 17 miles NE. by N. ¾ N. of Thunder Bay Island, July

2, 1923, 20 miles E. by N. of the can buoy, and July 5, 1923, 18 miles NE. ¾ E. of Thunder Bay Island (records 30 to 33). On October 27, 1917, 35 miles NE. by N. ¾ N. of Harbor Beach, Mich., in 50 fathoms (record 36), it was also rare. In three lifts made in 60 to 64 fathoms on August 30, 1919, 18 miles N. by E. ½ E. of Thunder Bay Island, September 3, 1919, 28 miles E. ¼ S. of the can buoy, and July 7, 1923, 13 miles NE. ½ N. of Thunder Bay Island, *zenithicus* comprised 14 to 17 per cent of the catches. In Georgian Bay it has been found absent or rare among the fish seen in seven lifts of the 3-inch nets, the number not including the sets on the spawning grounds of the longjaw (records 38 and 39.)

In less than 35 fathoms the 4½-inch trout nets, the 1½-inch bait nets, and the 2¾-inch chub nets set under my direction with the 4½-inch gangs have taken the species. While it never was abundant or even common in the 4½-inch nets off Alpena, Mich., in September, 1917, and in July, 1923, there are more records for it in these nets than for any other species of chubs. (Records 9, 11, 12, 13, 14, 22, and 35.) The 2¾-inch nets set with the trout nets brought in only one fish on September 17, 1917, from 15 fathoms (record 16), and September 26, 1917, from 17 fathoms (record 23); six on September 19, 1917, from 30 fathoms (record 19); and none on November 2, 1917, from 15 fathoms. Thus the fish were not shown more abundant by these nets than by the 4½-inch nets. In the 1½-inch bait nets at 30 fathoms occasional specimens were taken off Cheboygan, Mich., on October 15, 1919 (record 4), and off Alpena, Mich., on September 8, 1917, and September 16, 1919 (records 10 and 29). Off Harbor Beach, Mich., on March 15, 1919, 12 per cent of the small fish examined from a catch of the bait nets were *zenithicus* (record 37). A single specimen was taken in the special 1½-inch net set off Presque Isle Light in 60 fathoms on September 13, 1919 (record 28). In view of the fact that the fish spawn in 35 to 50 fathoms, it would be expected that immature fish would be more common in these nets than the records show. However, the evidence from this source is scant and is by no means conclusive.

All the records thus indicate that during the summer and early fall *zenithicus* is not common in nets of any class except in the 2¾-inch nets set on its spawning grounds in the north end of the lake. It should be noted, however, that most of the records indicating relative abundance have been made during, shortly before, or after the spawning period, which falls between the middle of September and the middle of October. If *zenithicus*, like most other fish, seeks spawning grounds in water shallower than that in which it feeds, then the maximum density of its population may be looked for at depths greater than 35 to 50 fathoms.

BREEDING HABITS

Only in 35 to 50 fathoms northward from Forty Mile Point were *zenithicus* found abundantly. On September 28 and 29 and October 14, 1917, lifts from these grounds examined by me contained this species almost exclusively. At this period the fish were spawning. Males were taken with pearls, and females were full of ripe eggs, except on the latest date, when many were nearly spent or spent. The fishermen say that the fish begin to move onto the clay bottom between Spectacle Reef and Forty Mile Point in 30 to 50 fathoms toward the middle of September. At first they run into 30 fathoms but move out later to 40 to 50 fathoms to spawn. Records of the

fishing tugs show that the movement began about September 13 in 1915. From this date until October 8 from 2,100 to 4,400 pounds of fish were taken daily from 5 miles of nets lifted after having been set two and three nights. Previous to this run 1,000 to 1,500 pounds in nets five nights out were considered good lifts. After October 8 the weight of the lifts dropped rapidly. On the 8th, 2,450 pounds were taken; on the 9th, 1,555 pounds; on the 19th, 595 pounds; on the 20th, 520 pounds. What becomes of the fish after they leave the spawning grounds is unknown. Certainly they do not return in any numbers before June, because few chubs of any kind are caught here from the opening of navigation until June.

These are the only spawning grounds known. The occurrence of small individuals in the 1½-inch nets at Harbor Beach, Mich., in March, 1919, indicates that the species also spawns somewhere in the southern part of the lake. An occasional female among these individuals shows large but not ripe eggs, and an occasional male has well-developed testes and a trace of nuptial pearls. Most of the specimens, however, exhibit sex organs apparently normal for the species. It is possible that specimens spawning for the first time mature irregularly, an assumption that is strengthened by the finding of small specimens of this species in Lake Superior with ripe eggs in June (see p. 384).

FOOD

Only seven stomachs were examined from specimens collected in September, 1917, off Cheboygan, Mich. Mysis and Pontoporeia comprised 95 per cent of the food. Pisidium, pebbles, wood fragments, larval chironomids, and unidentifiable bottom material constituted the rest.

LEUCICHTHYS REIGHARDI Koelz

REIGHARD'S CHUB (FIGS. 17 AND 18)

Leucichthys reighardi Koelz, 1924, pp. 5–8, Lake Michigan; Dymond, 1926, pp. 65–66, Pl. VII, Lake Nipigon.

Leucichthys reighardi has been described from southern Lake Michigan. Races of the species also occur, so far as is known, in the northern part of that lake and in Lakes Ontario, Superior, and Nipigon. In all four lakes it is represented by relatively small decidedly terete fishes with included mandible, relatively few gill rakers on the branchial arches, few scales in the lateral line, short paired fins (except in Nipigon), and short snout. Each race, however, has its own peculiarities, but it seems desirable to name only the two extremes of development. The race in Lake Ontario is nearly like the typical one, differing chiefly in the relatively somewhat smaller size of head and eye. In both lakes the forms appear to prefer the shallower waters and to spawn in May or June. The race of northern Lake Michigan tends to have a longer snout and maxillary. The Superior and Nipigon forms show more differences, and the Nipigon form, which shows the extreme development, has been named *dymondi*. These two forms differ from the typical one chiefly in the relatively longer head, maxillary, and pectoral fins, fewer scales in the lateral line, greater number of dorsal and anal rays, in the reduction of the pigmentation of the head, and in the less vertical position of the premaxillaries. The Nipigon race also differs slightly in a few other proportions. Both races likewise prefer shallow water but spawn probably in November.

Type

The type is a female specimen (catalogue No. 87351, U. S. National Museum), 210 millimeters in length, collected in Lake Michigan on April 1, 1921, off Michigan City, Ind., in 30 fathoms of water. Counts of certain multiple parts and proportional lengths for this specimen are shown in Table 33. Certain numerical expressions of type characters are repeated in the description.

Leucichthys reighardi reighardi of Lake Michigan

Reighardi is one of the smaller chubs, ranking in respect to size with *kiyi* and *hoyi*. The largest specimen collected measures only 278 millimeters in length, and most of the fish seen have been smaller than 240 millimeters. The body is little compressed, much less than in any other member of the genus excepting *artedi*, and, as seen from the side, tapers smoothly and regularly to the head and tail from the deepest portion of the body, which is through a point at the front of the dorsal. In most of the specimens at hand the depth at this point is 22 to 26 per cent of the total length. Occasionally an individual is taken in which this figure rises to 29 per cent, and in such specimens the predorsal profile is steeper over its anterior half.

The head is of medium size, moderate depth, bluntly triangular in side view, its dorsal contour (not including the premaxillaries) straight or faintly curved. It is contained 4.4 [(3.9) 4.1–4.5 (4.8)][50] times in the total length.

The snout is relatively short and is contained 3.8 [(3.2) 3.4–4 (4.4)] times into the head length. In side view it is usually truncate on account of the nearly vertical position of the premaxillaries. The premaxillaries are always heavily pigmented and usually make an angle of 60° to 70° with the horizontal axis of the head, so that their tip is usually at or below the lower edge of the pupil. The maxillary is always more or less pigmented, the cutting edge usually rimmed with black halfway to its distal end. It is contained 2.7 [(2.3) 2.5–2.8 (3)] times in the head length. The lower jaw is always shorter than the upper and is usually heavily tipped with black. The maxillary plus snout divided by eye equals 2.3 [(2.2) 2.4–2.6 (2.8)][51] in south; in north [(2.2) 2.5–2.7 (3.1)].[52] The eye is relatively large and is contained 3.8 [(3.6) 3.9–4.2 (4.6)] times in the head length. It is situated in the second quarter of the head's length, encroaching more or less on the third. The gill rakers on the first branchial arch number 14+23 [(11) 12–14 (16)+(19) 21–24 (27)=(30) 34–38 (43)].[53] The lateral line is nearly straight; its scales number 74 [(66) 72–81 (96)].[53] Rows of scales around the body in front of the dorsal and ventrals number 41 [(38) 40–43 (46)];[54] in front of the adipose and anus 31 [(30) 32–35 (39)];[54] around the caudal peduncle at its commencement 22 [22–24 (26)].[54]

The dorsal fin is relatively low and has 9 [(8) 9–10(11)][55] rays. The anal rays number 10 [(9) 10–11 (12)];[56] the ventral rays 11 [10–12];[56] the pectoral rays 16

[50] The ratios given in brackets (except where otherwise noted) are based on an examination of 314 specimens, among them 145 paratypes, ranging in length from 200 to 278 millimeters.

[51] One hundred and thirty-three specimens 200 millimeters or more in length.

[52] One hundred and fifty-eight specimens 200 millimeters or more in length.

[53] Four hundred and six specimens of all sizes.

[54] Thirty-one specimens.

[55] One hundred and seventy-nine specimens.

[56] Forty-four specimens.

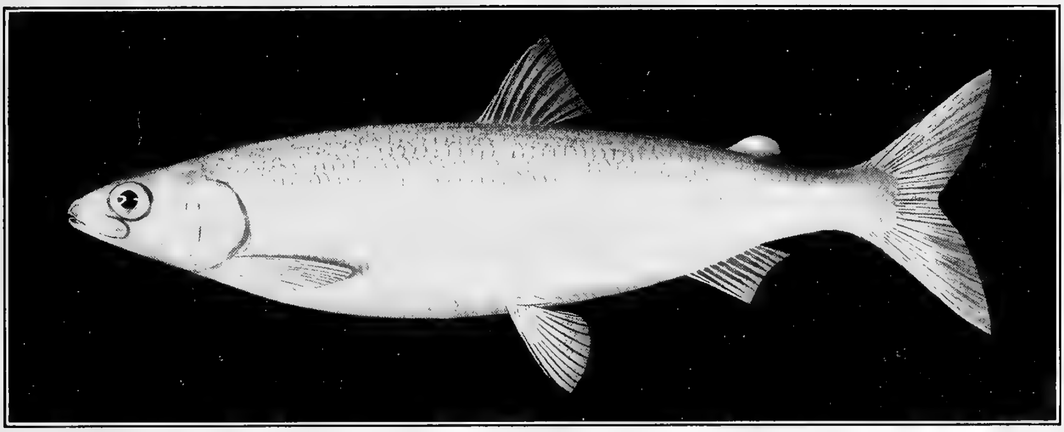

FIG. 17.—*Leucichthys reighardi* Koelz, Reighard's chub. Female (type), 210 millimeters long, taken in Lake Michigan off Michigan City, Ind., in 30 fathoms on April 1, 1921

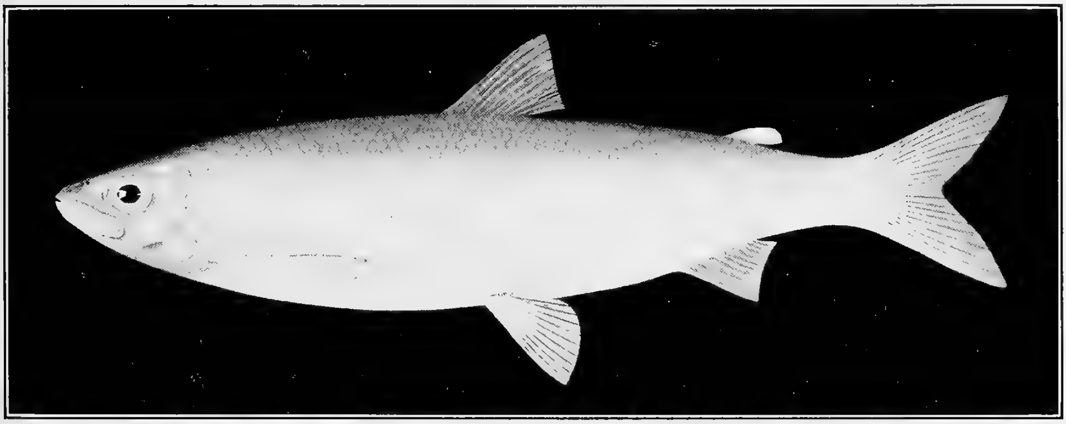

FIG. 18.—*Leucichthys reighardi dymondi* Koelz. Male, 223 millimeters long, taken in Lake Superior in Thunder Bay on November 25, 1922

[15–17].[56] The paired fins are short. The pectoral length divided into the distance from its insertion to that of the ventral equals 2.1 [(1.7) 2.0–2.5 (2.8)]. The length of the ventral is contained 1.4 [(1.2) 1.4–1.7 (1.9)] times in the distance from its origin to the anal.

The color of living specimens differs in only minor details from that of other chubs. After preservation, as in all species, pigmentation becomes more conspicuous. The entire dorsal surface is pigmented more or less heavily and evenly. The pigment becomes denser in the prenarial area and usually shows very dark on the premaxillaries and on the tip of the mandible. It continues often in a black rim along the cutting edge of the maxillaries. The preorbital area, the postoculars, and at least half of the maxillary are pigmented abundantly. On the cheeks and on the sides of the body pigment diminishes rather gradually as the ventral surface is approached. It is absent on the belly. Often the dorsal border of the pectoral and sometimes the inner surface of its longest rays are lined with pigment. The cranial margin and a wide distal band of the dorsal and the lateral borders, the distal third of the longest and half of the shortest rays of the caudal are smoky to black in hue. A few dots of pigment are often evident on the membrane of the anal. The ventrals are usually immaculate but may show more or less pigment, especially in the north.

Males and at least some females acquire pearl organs during the breeding season. There are no specimens available from which to prepare a description of the pearls at the height of their development, but one male taken on August 18, 1920, off Washington Harbor, Wis., exhibits nuptial adornment about like that described for *johannæ* on page 350.

VARIATIONS

Racial variations.—Specimens taken in the northern waters are, on the average, different from those of the southern half of the lake. Northern fish tend to have a longer snout and maxillary and, as has been stated previously, average more pigmented on the fins. Some specimens have these parts developed to so great a degree that they resemble closely specimens of *zenithicus*. The values of these two characters in northern and southern specimens 200 millimeters or more in length are given below. The specimens have been divided according as their origin is north or south of a line drawn south of Washington Island, Wis., and Frankfort, Mich.

H/S:	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4
Northern fish	1	3	28	27	41	30	17	13	4	2	0	1	--
Southern fish	--	--	--	4	18	35	22	22	22	8	1	0	1

H/M:	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3
Northern fish	1	8	35	46	44	24	4	2
Southern fish	--	--	3	38	50	37	7	--

MS/E:	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3	3.1
Northern fish	2	5	12	20	46	39	17	12	4	1
Southern fish	2	15	41	36	32	5	2	--	--	--

Size variations.—In Table 33, 20 specimens are compared extensively, half of them less than 200 millimeters in length and half of them more than 200 millimeters. In Tables 8 to 11 values for several characters are given for all the specimens of the

[56] Forty-four specimens.

collection, similarly separated according to size. From these tables it may be seen that the only differences recognizable in the two classes are differences of proportion. It appears that the head and eye are proportionally but slightly larger in the smaller specimens, while the snout is shorter and the body depth is less, of course.

The smallest specimens that were collected at Sheboygan, Wis., on September 28, 1920 (144 to 150 millimeters), showed developing sex glands and probably would spawn at the succeeding spawning season. Occasional specimens under 170 millimeters have been found to be immature, however.

COMPARISONS [57]

Reighardi is most like *zenithicus* in appearance. A discussion of the differences between the two forms is given on page 389. *Reighardi* is compared with *johannæ* and *alpenæ* on pages 351 and 365.

Reighardi differs from *nigripinnis* in its more elliptical body shape as seen from the side, its shorter and more included mandible, paler body and fins, wider body, fewer gill rakers on the first branchial arch and lateral-line scales, and much shorter paired fins. Certain of these characters are compared below:

Gill rakers on the first branchial arch:
- *reighardi*, (30) 34–38 (43), with 3 per cent more than 40.
- *nigripinnis*, (41) 46–50 (52).

Lateral-line scales:
- *reighardi*, (66) 72–81 (96), with 26 per cent more than 79.
- *nigripinnis*, (74) 80–87 (89), with 84 per cent more than 79.

Pv/P:
- *reighardi*, (1.7) 2–2.5 (2.8), with 97 per cent more than 1.8.
- *nigripinnis*, (1.5) 1.6–1.8 (2.2), with 18 per cent more than 1.8.

Av/V:
- *reighardi*, (1.2) 1.4–1.7 (1.9), with 42 per cent more than 1.5.
- *nigripinnis*, 1.2–1.5 (1.6), with 8 per cent more than 1.5.

As *reighardi* spawns in the spring and *nigripinnis* in the winter, the state of ripeness of the sex products also may serve as a distinguishing character.

Reighardi is distinguishable from *kiyi* by the body shape, which is subterete in the former and subfusiform in the latter; by the length of the mandible, which in *reighardi* is always included in the upper jaw while in *kiyi* it is equal to or usually longer than the upper jaw; and by the smaller, less sharply triangular head and shorter paired fins. Comparative figures for certain of these characters follow:

L/H:
- *reighardi*, (3.9) 4.1–4.5 (4.8), with 85 per cent more than 4.1.
- *kiyi*, (3.7) 3.8–4.1 (4.3), with 8 per cent more than 4.1.

Pv/P:
- *reighardi*, (1.7) 2–2.5 (2.8), with 96 per cent more than 1.9.
- *kiyi*, (1.1) 1.4–1.7 (2.1), with 4 per cent more than 1.9.

Av/V:
- *reighardi*, (1.2) 1.4–1.7 (1.9), with 91 per cent more than 1.3.
- *kiyi*, (0.96) 1–1.3 (1.4), with 2 per cent more than 1.3.

As *reighardi* spawns in spring and *kiyi* in fall, females usually are distinguishable by the condition of the ovaries.

---

[57] Figures given in this section for proportions are based on specimens 200 millimeters or more in length. Counts are given for specimens of all sizes.

Reighardi differs from *hoyi* in having the lower jaw shorter while in *hoyi* it is usually equal to or longer than the upper; in having fewer gill rakers on the first branchial arch and shorter paired fins, as will appear from the comparisons:

Gill rakers on the first branchial arch:
reighardi, (30) 34–38 (43), with 3 per cent more than 40.
hoyi, (37) 41–44 (48), with 86 per cent more than 40.

Pv/P:
reighardi, (1.7) 2–2.5 (2.8), with 83 per cent more than 2.
hoyi, (1.6) 1.8–2 (2.3), with 21 per cent more than 2.

Av/V:
reighardi, (1.2) 1.4–1.7 (1.9), with 91 per cent more than 1.3.
hoyi, (1.1) 1.3–1.5 (1.7), with 60 per cent more than 1.3.

In addition, *reighardi* has, on the average, a proportionately shorter head and maxillary and more lateral-line scales. *Reighardi* spawns in May or June and *hoyi* in March, so that at times the state of development of the sex organs also may be of aid in separating the species.

Reighardi is distinguishable from *artedi* by the fewer gill rakers on the first branchial arch, which seldom are more than 41 in the former and not less than 41 in the latter, and a less triangular head, as seen from the side. The snout of *reighardi* is sharply truncated in front by the nearly vertical position of the premaxillaries. *Reighardi* has, on the average, shorter pectorals, a somewhat longer maxillary, the mandible is more conspicuously tipped with black, and the back is usually paler in color. *Reighardi* spawns in the spring and *artedi* in the fall, so that the state of development of the sex organs may serve as a differentiating character at times.

GEOGRAPHICAL DISTRIBUTION

Table 32 shows my data on the occurrence of *reighardi* in Lake Michigan. They are shown platted on a chart of the lake in Figure 4. There are 43 records, all but 14 of them made from the commercial chub nets. While the species seldom has been found in numbers, a few individuals have been present in most lifts examined, even in that one made on the Sheboygan reef (record 8); and it may be stated safely that the species is distributed along the shores of the lake and probably on some of the reefs.

BATHYMETRIC DISTRIBUTION

Data on the depth range of *reighardi* have been collected principally from an examination of the lifts of the 2⅜ to 2¾ inch chub nets set at depths of 12 to 90 fathoms. All the chub lifts examined have yielded at least a few examples of this species, except those made off Milwaukee, Wis., on September 24, 1920, 9 miles NNE. in 22 to 25 fathoms and on November 15, 1920, 20 miles ESE. in 28 to 35 fathoms, and that made on November 19, 1920, 10 miles northwest of Michigan City, Ind., in 18 fathoms. The two last were made on the spawning grounds of *zenithicus*, and it is not surprising that no *reighardi* occurred there, while the former was made on grounds unfrequented by chubs of any species. In Green Bay, where 2⅜ to 2¾ inch nets are set for herring, *reighardi* was seen only in those nets set in the deepest water. A few individuals were taken in a gang of nets on August 18, 1920, off Boyer Bluff, Washington Island, Wis., in 18 to 24 fathoms (record 1).

In the catches of the 1½-inch bait nets examined from seven ports (see p. 354) small *reighardi* were found always. Lifts were examined from depths of 26 to 40

fathoms from off Sheboygan, Port Washington, and Racine in Wisconsin, Michigan City, Ind., and Manistee, Northport, and Traverse City in Michigan (records 9, 12, 16, 23, 28, 33, and 35). They were present, also, in a lift of special nets made from 8 to 12 fathoms in Platte Bay, Mich., on July 21, 1923, and in a lift from 6 to 16 fathoms off Traverse City, Mich., on July 25, 1923 (records 31 and 36).

In the 4 to 4½ inch trout nets examples of the species were brought in at Washington Harbor, Wis., on August 18, 1920, from 20 to 24 fathoms; at Ludington, Mich., on August 30, 1920, from 14 to 26 fathoms; and at Manistee, Mich., on August 28, 1920, from 28 to 32 fathoms (records 3, 4, 27, and 29). At Sheboygan, Wis., on September 28, 1920, 3½-inch nets lifted from 35 to 40 fathoms had specimens also (record 8).

From these observations it appears that *reighardi*, when not spawning, ranges between 6 and 90 fathoms. These data do not give the outside limits of the range, however.

RELATIVE ABUNDANCE

I have stated elsewhere, in discussing the relative abundance of other species of chubs, that conditions were decidedly unfavorable during the collecting season of 1920 for the accumulating of data necessary for conclusive statements on this head. In those lifts of the chub nets mentioned in the preceding section no *reighardi* were seen. In most of the other chub lifts examined there were found only a few fish of this species. Examples of the species were rare or found only occasionally among the catches of other Leucichthys in lifts made on August 18, 1920, 4 miles west of Boyer Bluff in 18 to 24 fathoms (record 1); August 19, 1920, 20 miles E. ½ N. of Rock Island in 71 to 90 fathoms (record 5); August 23, 1920, 12 miles E. by S. of the Sturgeon Bay ship-channel mouth in 60 to 70 fathoms (record 6); August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms (record 7); September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms (record 11); September 23, 1920, 27 miles ESE. of Milwaukee, Wis., in 60 fathoms (record 15); September 3, 1920, 22 miles NW. by N. ½ N. of Michigan City, Ind., in 30 to 40 fathoms, October 11, 1920, 20 miles N. by W. ¾ W. in 30 to 40 fathoms, November 8, 1920, 18 miles NNW. in 30 to 38 fathoms, November 19, 1920, 17 miles NNW. and 17½ miles NW. by N. ¾ N. in 28 to 32 fathoms, and on March 4, 1921, 15 miles NW. by N. ½ N. in 28 fathoms (records 17, 18, 19, 20, 21, and 24); on October 4, 1920, 9 miles north of Point Betsie in 60 to 70 fathoms (record 30); August 10, 1923, 8 miles off Big Rock Point; June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55 fathoms; from an unknown locality on August 21, 1923 (records 37, 39, 41); on June 22, 1920, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms (record 32); and on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms (record 43). In one lift examined at Michigan City on March 2, 1921, made 21 miles NNW. in 30 fathoms; in a lift made July 31, 1923, 5 miles northwest of Cathead Light in 40 to 60 fathoms; and in a lift made August 11, 1923, 3 miles NW. ½ W. of Charlevoix in 35 to 60 fathoms (records 22, 34, and 40), from 16 to 41 per cent of the catch was made up of *reighardi*. In a letter of April 25, 1921, referring to 47 specimens of *reighardi* sent me for examination, taken on April 1, 1921, off Michigan City in 30 fathoms (record 25), Robert Ludwig writes that about 30 per cent of the entire lift on that date were fish belonging to the species sent. A sample of chubs caught on May 26, 1921, 8 miles northeast of Port Washington, Wis.,

in 20 to 35 fathoms, by D. H. Smith & Sons (record 13), was found on examination to be chiefly *reighardi*.

In the 1½-inch bait nets, lifts made from 28 to 40 fathoms on September 28, 1920, 5 miles SE. by E. of Sheboygan, Wis.; on June 23, 1920, off Northport Point; and on July 18, 1923, in West Traverse Bay, from 20 to 30 per cent of the small fish gilled were *reighardi* (records 9, 33, and 35). They were rare in similar lifts made off Port Washington, Wis., on September 25, 1920, and on March 2, 1921, off Michigan City, Ind., in 26 to 30 fathoms (records 12 and 23). The special 1½-inch nets set in Platte Bay on the Michigan shore, in West Traverse Bay, and off the South Manitou Island in July, 1923, in 4 to 25 fathoms (see Table 68) took few or no specimens of this species (records 31 and 36).

It appears from these data that for unknown reasons few *reighardi* were taken in the chub nets during the summer and fall of 1920. On several occasions in later years it has been found common in the chub hauls. The records of maximum abundance are from lifts made between 30 and 60 fathoms. Inasmuch as juvenile specimens have been taken commonly in the bait nets, and occasional specimens have been found ensnarled in the trout nets, both of which are set regularly at less than 40 fathoms, it seems probable that the species prefers the shallower waters and that, therefore, the above-mentioned limits indicate more or less closely the zone of maximum density for the species.

BREEDING HABITS

The time and places of spawning are not definitely known. There are, however, data bearing on both, which are worthy of consideration. Of the fish examined at Michigan City, Ind., on March 2, 1921, at Grand Haven, Mich., on March 20, 1919, and Milwaukee, Wis., on March 24, 1919, most of the males showed pearl organs and emitted milt on pressure and the females exhibited ova nearly fully developed. The specimens received from Michigan City on April 1, 1921, had sex organs in about the same stage of development, except that 2 of the 26 females were spent. Of 39 females received from Charlevoix, Mich., taken on May 3, 1924, 7 were spent, 1 was spawning, and most of the rest had eggs nearly ripe. Males received from Port Washington, Wis., on May 26, 1921, had no pearls (these structures are very frail and are removed easily by friction), but milt was exuded, and the females had ova nearly mature. It should be pointed out, in this connection, that if the nets were not actually set on the spawning grounds only spent or unripe fish would be taken, and the data just reviewed do not indicate more than that the specimens were taken at a period not remote from the spawning season. At Northport, Mich., on June 22, 1920, and at Charlevoix on June 29, 1920, females were collected that were spent or still had some eggs in the body cavity. Female specimens taken thereafter exhibited ovaries in which the eggs of a new season were appearing, but an occasional pearled male or a female with retained ripe eggs was taken at Washington Harbor, Wis., on August 18, 1920; at Sturgeon Bay, Wis., on August 23, 1920; at Algoma, Wis., on August 24, 1920; at Michigan City, Ind., on September 3, 1920; and at Port Washington, Wis., on September 25, 1920. Whether these abnormal individuals matured their sex products with the rest and were not relieved of them normally or whether the germ cells ripened at abnormal periods is uncertain. The examination of the sexual condition of collected specimens thus indicates that spawning must occur sometime between the last of March or first of April and the last of June.

There is circumstantial evidence offered in the testimony of D. H. Smith & Sons, of Port Washington, Wis., who on May 26, 1921, sent the samples of chubs of which *reighardi* comprised the majority, which indicates that spawning grounds for the species are found near Port Washington. Mr. Smith states that a heavy run of chubs began during the last week of April and continued until the middle of June on grounds 3 to 4 miles E. to NE. by N. of Port Washington. The nets were run along the beach at depths of 14 to 35 fathoms on bottom of "dirty sand with some showing of mud." As heavy runs of chubs examined from other ports have been found to consist of spawning fish of some species, it is likely that this run consisted of spawning *reighardi*. *Hoyi*, the only other spring spawner, spawns in March. The finding of a majority of *reighardi* approaching the spawning condition in the sample of fish taken on these grounds on May 26, 1921, and the coincidence of the dates of this run with the period during which the species must spawn (according to an examination of the sexual condition of specimens collected at various times and places) confirm the assumption. Mr. Smith states that to his knowledge the fishermen of no neighboring ports found the run, but he is of the opinion that a trial on suitable grounds probably would have been fruitful.

Evidence of two kinds thus indicates that *reighardi* spawns probably in May and early June at depths of 14 to 35 fathoms on a muddy sand bottom.

Leucichthys reighardi dymondi (new subspecies) of Lake Nipigon

The Nipigon race (fig. 18) differs more markedly from the typical form than any of the other races but is much like the Superior race. The characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (31) 35–38 (43).[58]
- Nipigon, (32) 33–36 (38).[59]

Lateral-line scales:
- Michigan, (67) 72–81 (96).[58]
- Nipigon, (64) 66–73 (77).[59]

L/H:
- Michigan, (4) 4.2–4.5 (4.8).
- Nipigon, (3.5) 3.7–3.9 (4.1).

H/E:
- Michigan, (3.6) 3.9–4.2 (4.4).
- Nipigon, (3.6) 4–4.4 (4.8).

H/M:
- Michigan, (2.5) 2.6–2.8 (3).
- Nipigon, (2.2) 2.3–2.5 (2.7).

H/S:
- Michigan, (3.5) 3.7–4 (4.4).
- Nipigon, (3.3) 3.5–3.6 (4).

Pv/P:
- Michigan, (1.8) 2.1–2.4 (2.8).
- Nipigon, (1.4) 1.6–1.8 (2).

Av/V:
- Michigan, (1.2) 1.4–1.7 (1.8).
- Nipigon, (1.1) 1.3–1.6 (1.7).

L/D:
- Michigan, (3.5) 3.8–4.3 (5).[60]
- Nipigon, (3.5) 3.6–4.1 (4.4).

Scale rows:
1. Michigan, (38) 40–43 (46).[61]
   Nipigon, (37) 39–41 (43).[62]
2. Michigan, (30) 32–35 (39).[61]
   Nipigon, (30) 31–33 (34).[62]
3. Michigan, 22–24 (26).[61]
   Nipigon, 22–24.[62]

Dorsal rays:
- Michigan, (8) 9–10 (11).[63]
- Nipigon, (9) 10–11.[62]

[58] These figures for Lake Michigan are based on an examination of 192 specimens of all sizes from the southern sector of the lake. Most of them are paratypes. All unmarked figures are given for 146 specimens ranging in length between 200 and 243 millimeters.

[59] These figures for Lake Nipigon are based on an examination of 98 individuals ranging in length between 145 and 304 millimeters. Unmarked figures are given for 83 specimens 200 millimeters or more in length.

[60] One hundred and eleven specimens over 200 millimeters.

[61] Thirty-one specimens.

[62] Eighteen specimens.

[63] One hundred and seventy-nine specimens.

It appears, thus, that the Nipigon race has fewer scales in the lateral line and fewer scale rows and somewhat fewer rakers, more dorsal rays, a proportionally longer head, snout, maxillary, and paired fins, and a proportionally smaller eye, and a deeper body. The premaxillaries also are less vertical in position. The two forms are alike as concerns body shape, as seen from the side, in having an included lower jaw (though in *dymondi* the mandible is proportionally longer and not so invariably included), and in the small size attained. (Extreme examples obtained after extensive collecting in virgin waters measure only 304 millimeters.)

This form appears sufficiently distinct to merit a name and is here designated as *dymondi*. The type is specimen No. 57467, described in detail in Table 35. It is catalogued as No. 88353, U. S. National Museum.

Living specimens are paler in color than those from Lake Michigan, and preserved specimens show reduced pigment. The prenarial area is not conspicuously darker, and the mandible tip is never black. The maxillary may be immaculate occasionally and frequently is pigmented over only one-fourth its surface; the paired fins and the anal are frequently immaculate. Usually, however, there is at least a rim of pigment on the dorsal edge of the pectorals, and sometimes there is pigment on them all.

One male specimen collected on July 26, 1922, showed traces of pearl organs, and it is likely that at least all males develop them in the breeding season.

VARIATIONS

Racial variations.—There are not sufficient specimens available for examination to determine whether there are intraspecific variations.

Size variations.—In Table 35 are compared extensively 10 specimens more than 200 millimeters in length and 9 specimens 200 millimeters in length or smaller. A few small fish are compared with larger ones for several characters only in Tables 8 to 11. Small fish seem to have a proportionally larger eye, shorter snout, and less body depth. The base of the dorsal and of the anal and the gill rakers also appear to be somewhat longer, and the dorsal and anal rays are less in the small fish, though the lower number of rays no doubt is due to the exclusion from the individual counts of one of the first rays, which are apt to be shorter in small specimens.

The few specimens examined indicate that individuals that have attained a length of 170 millimeters by the middle of the summer are sexually mature.

COMPARISONS [64]

The low gill-raker count will distinguish *reighardi* from any of the Nipigon Leucichthys except *zenithicus*. A discussion of the differences between *reighardi* and *zenithicus* is given on page 386.

Reighardi differs from *nigripinnis regalis* in having a much more elliptical body shape (seen from the side), a shorter, more included mandible, a much paler body and fins, and a smaller eye. The comparative figures for gill rakers and eye size follow:

Gill rakers on the first branchial arch:
- *reighardi*, (32) 33–36 (38).
- *nigripinnis*, (44) 48–51 (54).

H/E:
- *reighardi*, (3.6) 4–4.4 (4.8), with 44 per cent more than 4.1.
- *nigripinnis*, (3.5) 3.7–4.1 (4.3), with 5 per cent more than 4.1.

[64] The specimens in this section compared for proportions are those 200 millimeters or more in length, except in the case of *artedi*, where they are 225 millimeters or more. The counts are given for specimens of all sizes.

Reighardi has on the average fewer lateral-line scales, a somewhat longer head and snout, and shorter paired fins.

Reighardi differs from *hoyi* in having a shorter, more included, and less hooked mandible, less sharply triangular head (as seen from the side), fewer gill rakers on the first branchial arch, and fewer lateral-line scales. The comparative figures for the last-named characters follow:

Gill rakers on the first branchial arch:
- *reighardi*, (32) 33–36 (38).
- *hoyi*, (40) 42–46 (48).

Lateral-line scales:
- *reighardi*, (64) 66–73 (77), with 23 per cent more than 72.
- *hoyi*, (66) 73–80 (85), with 82 per cent more than 72.

Reighardi has also on the average a somewhat smaller eye and shorter ventrals.

Reighardi has many fewer gill rakers on the first branchial arch than *artedi* or *nipigon*; also fewer lateral-line scales and a longer snout and maxillary. These characters are compared below:

Gill rakers on the first branchial arch:
- *reighardi*, (32) 33–36 (38).
- *artedi*, (41) 46–49 (53).
- *nipigon*, (54) 56–59 (66).

Lateral-line scales:
- *reighardi*, (64) 66–73 (77), with 23 per cent more than 72.
- *artedi*, (65) 71–76 (81), with 59 per cent more than 72.
- *nipigon*, (68) 72–77 (82), with 80 per cent more than 72.

H/S:
- *reighardi*, (3.3) 3.5–3.6 (4), with 24 per cent more than 3.6.
- *artedi*, (3.5) 3.7–3.9 (4.2), with 92 per cent more than 3.6.
- *nipigon*, (3.3) 3.5–3.8 (4), with 55 per cent more than 3.6.

H/M:
- *reighardi*, (2.2) 2.3–2.5 (2.7), with 10 per cent more than 2.5.
- *artedi*, (2.5) 2.7–2.8 (3), with 98 per cent more than 2.5.
- *nipigon*, 2.5–2.7 (3.1), with 78 per cent more than 2.5.

Reighardi is also less pigmented throughout and has a proportionally longer head.

GEOGRAPHICAL DISTRIBUTION

In Table 34 are given the data of specimens collected by me with 2½ and 2¾ inch gill nets in 1922 and of specimens examined from the University of Toronto collection. These data are platted on the map of the lake in Figure 2. The records are distributed sufficiently widely over the lake to warrant the conclusion that *reighardi* occurs throughout the lake where it can find suitable conditions.

BATHYMETRIC DISTRIBUTION

There are few data to indicate the depth preferences of this species. Only three sets of the special 2½ and 2¾ inch gill nets were made by me in the lake, and *reighardi* occurred in two. Twenty per cent of the fish taken on July 25, 1922, off the source of Nipigon River in 10 to 15 fathoms (record 16), belonged to this species, while on the next day the catch off Macdiarmid in 30 fathoms had only 14 per cent of this species (record 2). It is interesting here to give the relative abundance of the

other species of the lake in these lifts for a comparison with the depth relations of these species as they are known in the Great Lakes. *Zenithicus* comprised 13 and 43 per cent of the catches, respectively; *nigripinnis* 30 and 38 per cent (both in others of the Great Lakes found in deeper waters); while the combined percentage of *artedi, nipigon,* and *clupeaformis* (shallow-water forms) was 35 and 3 per cent. Thus, in the set at 10 to 15 fathoms the deep-water *zenithicus* and *nigripinnis* had a combined percentage of 43, and in the 30-fathom lift 81; while the rest, including *reighardi,* which in other lakes show a preference for shallower water, had a combined percentage of 55 and 17. A set made off Livingston Point on July 28, 1922, in 56 fathoms took no *reighardi.* The specimens in the University of Toronto collection, so far as is known, also were taken in shallow water, but it is not possible to state what proportion of the catch they comprised.

All the data thus indicate that *reighardi* occurs regularly on the shoals of the lake, more abundantly in 10 to 15 fathoms than at 30, and is absent at 56 fathoms. These conclusions that the species prefers the shallower waters are quite in accord with the known habits of the species in the Great Lakes.

BREEDING HABITS

The specimens collected on October 26, 1922 (record 21), were not yet ripe but were near maturity. It is likely, then, that the spawning time falls in November, as in the case of the related form in Lake Superior. Nothing is known about the location or the character of the grounds selected for spawning.

Leucichthys reighardi dymondi (new subspecies) of Lake Superior

The Superior form (fig. 18) is most like that of Lake Nipigon but in severa particulars is rather intermediate between the Nipigon and Michigan forms. The principal systematic characters of the three forms that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (31) 35–38 (43).[65]
- Nipigon, (32) 33–36 (38).[66]
- Superior, (32) 34–38 (42).[67]

Lateral-line scales:
- Michigan, (67) 72–81 (96).[65]
- Nipigon, (64) 66–73 (77).[66]
- Superior, (65) 71–77 (83).

L/H:
- Michigan, (4) 4.2–4.5 (4.8).
- Nipigon, (3.5) 3.7–3.9 (4.1).
- Superior, (3.7) 3.9–4.2 (4.4).

H/E:
- Michigan, (3.6) 3.9–4.2 (4.4).
- Nipigon, (3.6) 4–4.4 (4.8).
- Superior, (3.6) 3.9–4.2 (5).

H/M:
- Michigan, (2.5) 2.6–2.8 (3).
- Nipigon, (2.2) 2.3–2.5 (2.7).
- Superior, (2.3) 2.4–2.6 (2.7).

H/S:
- Michigan, (3.5) 3.7–4 (4.4).
- Nipigon, (3.3) 3.5–3.6 (4).
- Superior, (3.4) 3.6–3.9 (4.1).

Pv/P:
- Michigan, (1.8) 2.1–2.4 (2.8).
- Nipigon, (1.4) 1.6–1.8 (2).
- Superior, (1.5) 1.8–2 (2.4).

Av/V:
- Michigan, (1.2) 1.4–1.7 (1.8).
- Nipigon, (1.1) 1.3–1.6 (1.7).
- Superior, (1.2) 1.4–1.7 (1.9).

[65] These figures for Lake Michigan are given for 192 specimens of all sizes from the southern sector of the lake; most of them are paratypes. Unmarked figures are given for 146 specimens ranging from 200 to 243 millimeters in length.

[66] These figures for Lake Nipigon are based on an examination of 98 individuals ranging in length between 145 and 304 millimeters. Unmarked figures are given for 83 specimens 200 millimeters or more in length.

[67] These and unmarked figures for Lake Superior are based on an examination of 234 specimens ranging in length from 199 to 320 millimeters.

Dorsal rays:
Michigan, (8) 9–10 (11).[68]
Nipigon, (9) 10–11.[69]
Superior, 10–11 (12).[70]

Anal rays:
Michigan, (9) 10–11 (12).[71]
Nipigon, (10) 11–12.[72]
Superior, (10) 11–12 (13).[73]

The mandible usually is included within the upper jaw, but it is not infrequently equal to it or longer. The premaxillaries are not usually vertical but make an angle of 55° to 65° with the horizontal axis of the head. The mandible seldom is pigmented, and the pigmentation of the prenarial area is much reduced, though the area is conspicuously darker still. The body is rather compressed, so that the body form is not subterete. The average size attained seems to be about the same for the Superior race as for the others, except that in virgin waters there are more fish larger than 250 millimeters. Only a single specimen longer than 290 millimeters has been seen, however.

Thus, it appears that in the matter of number of gill rakers, size of eye, and length of the ventral fins, the Superior form is very like the typical one. In respect to the number of dorsal and anal rays, the length of the mandible, position of the premaxillaries, and body width it is like the *dymondi* form. In the matter of number of lateral-line scales, length of head, maxillary, snout, and pectorals, and pigmentation of the head parts it seems to be more or less intermediate between the two. As the characters in which Superior specimens are predominantly like *dymondi* are more numerous and influence most their general appearance, I have called this form *dymondi* also.

The color of living specimens is much like that described for the Ontario race, except that the green of the back is paler, seldom being conspicuous beneath the overlying pigmentation. Specimens in spirits are pigmented on the ventral and anal more often than those of the typical form.

No specimens in full nuptial adornment have been collected. None of the males taken out of Port Arthur on November 25, 1922, showed pearl organs, but these fish were transported on ice, and friction had removed the epidermal structures. An occasional male taken in Thunder Bay in September, 1923, showed incipient pearl organs, and it is certain that in the breeding season, at least, the males are pearled.

VARIATIONS

Racial variations.—Virtually all my specimens are from Thunder Bay or the vicinity, so that nothing can be said about variations with locality.

Size variations.—Most of the specimens in the collection were taken in 2½-inch gill nets, so that they are too equal in size to furnish data on changes with growth.

COMPARISONS[74]

Reighardi resembles *zenithicus* most closely. The differences between these two species are discussed on page 380.

There is a close superficial resemblance to *artedi*, but there are sharp differences between the two species. *Reighardi* is not known to have more that 42 gill rakers on

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[68] One hundred and seventy-nine specimens.
[69] Eighteen specimens.
[70] Thirty-five specimens.
[71] Forty-four specimens.
[72] Eighteen specimens.
[73] Fifty specimens.
[74] Figures of proportions for *reighardi* and *nigripinnis* are based on specimens 200 millimeters or more in length; those for *artedi* on specimens 225 millimeters or more. Proportions for *kiyi* and *hoyi* and all counts are based on specimens of all sizes.

the first branchial arch, while *artedi* is not known to have less. *Reighardi* also has a longer head, a longer maxillary, longer paired fins, and fewer scales in the lateral line. A comparison of these characters for the two species follows:

L/H:
reighardi, (3.7) 3.9–4.2 (4.4), with 3 per cent more than 4.2.
artedi, (4) 4.3–4.6 (4.9), with 88 per cent more than 4.2.
H/M:
reighardi, (2.3) 2.4–2.6 (2.7), with 4 per cent more than 2.6.
artedi, (2.6) 2.7–3 (3.2), with 91 per cent more than 2.6.
Pv/P:
reighardi,(1.5) 1.8–2 (2.4), with 14 per cent more than 2.
artedi, (1.6) 2–2.3 (2.6), with 63 per cent more than 2.
Av/V:
reighardi, (1.2) 1.4–1.7 (1.9), with 3 per cent more than 1.7.
artedi, (1.3) 1.6–1.9 (2), with 36 per cent more than 1.7.
Lateral-line scales:
reighardi, (65) 71–77 (83), with 2 per cent more than 80.
artedi, (72) 84–93 (105), with 85 per cent more than 80.

Reighardi differs from *nigripinnis cyanopterus* in having fewer gill rakers, fewer scales in the lateral line, a larger eye, and a much more terete body. The comparative figures for certain of these characters follow:

Gill rakers on the first branchial arch:
reighardi, (32) 34–38 (42), with 10 per cent more than 38.
nigripinnis, (36) 38–42 (48) with 84 per cent more than 38.
Lateral-line scales:
reighardi, (65) 71–77 (83), with 2 per cent more than 80.
nigripinnis, (73) 79–86 (91), with 72 per cent more than 80.
H/E:
reighardi, (3.6) 3.9–4.2 (5), with 9 per cent more than 4.2.
nigripinnis, (4) 4.3–4.6 (5.2), with 85 per cent more than 4.2.

The paired fins also average shorter in *reighardi*, the dorsal contour of the pectoral usually is straight rather than decurved, and the body and fins are paler.

Reighardi is distinguishable from *kiyi* and *hoyi* by its more terete shape, its included mandible, greater adult size, fewer gill rakers on the first branchial arch, and shorter paired fins. *Reighardi* is further separable from *kiyi* by the fewer scales in the lateral line. The comparative figures for such of these characters as can be expressed accurately numerically are given below:

Gill rakers on the first branchial arch:
reighardi, (32) 34–38 (42), with 10 per cent more than 38.
kiyi, (36) 37–42 (45), with 71 per cent more than 38.
hoyi, (37) 40–45 (49), with 96 per cent more than 38.
Pv/P:
reighardi, (1.5) 1.8–2 (2.4), with 62 per cent more than 1.8
kiyi, (1.1) 1.3–1.5 (1.7).
hoyi, (1.4) 1.5–1.8 (2.2), with 11 per cent more than 1.8.
Av/V:
reighardi, (1.2) 1.4–1.7 (1.9), with 94 per cent more than 1.3.
kiyi, (0.9) 1–1.2 (1.4), with 1 per cent more than 1.3.
hoyi, (0.9) 1.1–1.3 (1.6), with 11 per cent more than 1.3.
Lateral-line scales:
reighardi, (65) 71–77 (83), with 2 per cent more than 80.
kiyi, (72) 76–84 (87), with 29 per cent more than 80.
hoyi, (65) 69–78 (84), with 2 per cent more than 80.

GEOGRAPHICAL DISTRIBUTION

Data in Table 36 and Figure 3 show *reighardi* in Superior to be confined to the western sector of the lake from Ontonagon, Mich., to Grand Marais, Minn., and to the islands blocking Nipigon Bay. The numerous sets of the special 2½ and 2¾ inch nets made in other parts of the lake (see Table 24) have not revealed it, but there is a bare possibility that it may occur elsewhere in habitats not explored.

BATHYMETRIC DISTRIBUTION

Pound nets were inspected only out of two ports on the north and west shores of the lake, and at each inspection some examples of this species were taken. Those gill-net sets in the area of distribution that were made near shore, so that part, at least, of the gang fished at moderate depths, have recorded the species. It has been absent from the special 2½ and 2¾ inch nets set within its distribution area only on October 4, 1921, off Bread Rock, Ontario, in 80 to 90 fathoms and on September 25, 1923, in Simpson Channel in 74 fathoms. It may be stated then, that in the summer, at least, *reighardi* runs onto the shoals and is known to range out to depths of 49 and possibly 65 fathoms, probably where such depths are attained in the proximity of shore.

RELATIVE ABUNDANCE

Reighardi has been taken commonly only in the bays and channels along the north shore of the lake.

Specimens of *reighardi* were rare among the Leucichthys taken in the 2½ and 2¾ inch nets lifted on August 24 and 25, 1921, 21 miles west and 6 miles NNW. of Ontonagon, Mich., in 15 to 45 and 20 to 38 fathoms (records 1 and 2); July 11, 1922, between Cat and South Twin Islands in 15 to 20 fathoms (record 3); July 17, 1922, 20 miles NE. by E. of Duluth in 30 to 40 fathoms (record 4); and on September 14, 1921, off Terrace Point, Minn., in 30 to 65 fathoms (record 5). In the northern bays it has been found common only in the shallower waters. Thus, in Thunder Bay and vicinity, in the lift of special 2½-inch nets made on September 15, 1923, between Silver Island and the mainland in 14 fathoms and inside Thunder Cape in 31 fathoms (records 8 and 9), and on September 17, 1923, inside the Welcome Islands in 11 fathoms and outside the Welcome Islands in 23 fathoms (records 10 and 11), and on September 19, 1923, in Thunder Bay off Sawyer Bay in 49 fathoms (record 12), *reighardi* constituted 32 to 92 per cent of the coregonids taken. Farther eastward, in the vicinity of Rossport, Ontario, in the lift made on September 25, 1923, in Moffat Strait in 13 to 14 fathoms, 17 per cent of the catch of coregonids was of *reighardi* (record 18.) It was rare in the lift made on September 29, 1923, off Salter Island in 42 fathoms (record 19). It was absent in the lift made on September 25, 1923, in Simpson Channel in 74 fathoms and on October 4, 1921, off Bread Rock in the main lake in 80 to 90 fathoms.

The species occurred in unknown numbers in the herring lifts made in Thunder Bay on November 25, 1922 (record 7.) These specimens were collected by H. Walmsley, of Booth Fisheries, from the herring fishermen. Testimony of these fishermen establishes that when the November herring run is on not infrequently 100 pounds or so of these fish are taken in a lift of several thousand pounds of herring,

especially at the beginning and close of the herring season. The herring nets are set in Thunder Bay in November at depths of 6 to 30 fathoms.

A number of specimens have been taken in the pound nets in Black Bay and the vicinity of Nipigon Bay. The pounds were of such large mesh that only the largest examples of the species were captured, and it is probable that the species was numerous even in the environs of the nets. Oscar Anderson, of Rossport, Ontario, in whose pounds most of the specimens were taken, stated that the large *reighardi* had been present in the Moffat Strait net for most of the summer of 1922, and that in early August, 1923, they were very common there.

From the data just reviewed it appears that *reighardi* occurs most abundantly along the shores of the bays and in the channels of the north shore. It has not been found common in water deeper than 49 fathoms, and no specimens have been taken from nets in water deeper than 65 fathoms. The temperature data in Table 13 show that the warmest waters in the lake are found within this zone of abundance.

BREEDING HABITS

An occasional male showing incipient pearl organs and exuding a little milt on pressure was taken in the lifts made in Thunder Bay on September 15 and 17, 1923 (records 9, 10, and 11), but most of the fish showed green gonads. None of the fish taken at Rossport, Ontario, on September 25 and 29, 1923 (records 18 and 19), showed indications of sexual ripeness. The majority of females taken at Port Arthur, Ontario, on November 25, 1922 (record 7), were spent, but the eggs of an occasional individual were still hard in the ovary. The males also were spent, though most of them yielded a little milt on pressure. The condition of the sex organs of these Port Arthur fish indicates that they had spawned recently. No spawning grounds of the species are known, but certainly some are to be found in Thunder Bay.

Leucichthys reighardi reighardi of Lake Ontario

The Lake Ontario form of *reighardi* resembles very closely the typical form. The principal characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
 Michigan, (31) 35–38 (43).[75]
 Ontario, (33) 35–38 (42).[76]
Lateral-line scales:
 Michigan, (67) 72–81 (96).[75]
 Ontario, (66) 73–81 (86).
L/H:
 Michigan, (4) 4.2–4.5 (4.8).
 Ontario, (4) 4.4–4.7 (5).
H/E:
 Michigan, (3.6) 3.9–4.2 (4.4).
 Ontario, (4) 4.2–4.5 (5).
H/S:
 Michigan, (3.5) 3.7–4 (4.4).
 Ontario, (3.3) 3.6–3.9 (4.2).
H/M:
 Michigan, (2.5) 2.6–2.8 (2.9).
 Ontario, (2.6) 2.7–2.9 (3).
Pv/P:
 Michigan, (1.8) 2.1–2.5 (2.8).
 Ontario, (1.7) 2.2–2.5 (2.9).
Av/V:
 Michigan, (1.2) 1.4–1.7 (1.8).
 Ontario, (1.3) 1.5–1.7 (2.1).

From the figures it appears that Ontario specimens tend to have a proportionally shorter head and smaller eye than the typical Lake Michigan form. These

[75] These figures are based on an examination of 192 specimens of all sizes. All other figures are given for 146 specimens ranging in length between 200 and 243 millimeters. Only fish taken in the southern sector of the lake are included in these tabulations. Most of them are cotypes.

[76] These and succeeding figures for Lake Ontario are based on 76 collected specimens ranging in length from 203 to 295 millimeters.

differences concern proportions that usually are affected by growth, and as of the two groups that of Lake Ontario contains the largest individuals, it would appear that the differences must lose in significance. The removal of the larger fish from the Ontario group reduces the disparity between the H/E figures for the two groups but alters little the L/H relations. (See section on "Size variations.")

While most of the individuals of the species taken in Lake Ontario have been of about the same size as those taken in Lake Michigan, a few exceptionally large examples have been taken. The largest of these measures 295 millimeters. These larger fish are usually conspicuously deeper than the smaller ones, and the anterior dorsal profile is not gradual, but the line rises rather rapidly for half the distance from the occiput to the dorsal and continues to the dorsal with only a slight upward trend.

The color of living specimens is like that of the chub and other Great Lakes Leucichthys. The underlying color of the back is usually pale pea green to blue green, though occasional individuals show bright tones. The iridescence is usually pinkish. In spirits specimens show, on the average, less pigmentation than the paratypes. The anal and ventrals are always immaculate, and the black of the snout and mandible is somewhat reduced.

The males and at least some females develop pearl organs during the breeding season. Among the specimens preserved, however, there are none that have retained more than traces here and there of the breeding adornment.

VARIATIONS

Racial variations.—Too few specimens have been obtained from any locality to permit extensive comparisons to ascertain whether there are racial differences within the species.

Size variations.—Only two specimens smaller than 200 millimeters have been seen, hence it is not possible to make the usual comparisons between small and large fish. The collected specimens may be divided, however, according as they are more or less than 250 millimeters in length, and some indication may be derived of the effect of growth on the systematic characters usually employed. Such a division leaves for comparison a group of 32 specimens 250 millimeters or more in length and a group of 44 smaller ones. The only marked difference between the characters of the two groups is in the H/E ratio—the larger fish have a proportionally smaller eye. The range of H/E for the small fish is 4–4.4 (4.5); for the larger ones (4) 4.2–4.6 (5).

COMPARISONS [77]

Reighardi is easily distinguishable from the other species in the lake on account of the fewer gill rakers on the first branchial arch and the shorter paired fins. A comparison of these characters follows:

Gill rakers on the first branchial arch:
- *reighardi,* (33) 35–38 (42), with 4 per cent more than 40.
- *hoyi,* (39) 42–47 (50), with 98 per cent more than 40.
- *kiyi,* (41) 43–46 (48).
- *artedi,* (41) 46–50 (54).

[77] Figures in this section are given for all collected specimens.

Pv/P:

reighardi, (1.7) 2.2–2.5 (2.9), with 89 per cent more than 2.1.
hoyi, (1.4) 1.7–2 (2.2), with 1 per cent more than 2.1.
kiyi, (1.5) 1.7–2 (2.2), with 3 per cent more than 2.1.
artedi, (1.7) 1.9–2.1 (2.5), with 15 per cent more than 2.1.

Av/V:

reighardi, (1.3) 1.5–1.7 (2.1), with 90 per cent more than 1.4.
hoyi, (1.1) 1.3–1.5 (1.6), with 38 per cent more than 1.4.
kiyi, (1) 1.2–1.4 (1.6), with 7 per cent more than 1.4.
artedi, (1.3) 1.5–1.8 (2), with 89 per cent more than 1.4.

Reighardi also has a less triangular head, seen from the side, a wider, more terete body, and the mandible is almost always shorter than the upper jaw, while in the other species, excepting *artedi* the reverse is true. In *artedi* the lower jaw has been found shorter than the upper in less than half the specimens examined. The body outline, as seen from the side, is more elliptical than in *kiyi;* and *reighardi* has also a shorter head, larger eye, and longer maxillary and snout than this species. It has a shorter head and maxillary than *hoyi.* As *reighardi* spawns in spring (probably in April or May) and *kiyi* spawns in August and *artedi* in November, the state of development of the sex organs may, at certain seasons, at least, aid in separating individuals of the several species.

GEOGRAPHICAL DISTRIBUTION

Data on the occurrence of *reighardi* given in Table 38 and shown platted on the chart in Figure 7 show that specimens of the species have been taken in the special 2½ and 2¾-inch nets out of every port visited on the New York shore and out of Brighton on the Canadian shore. Specimens have been seen also from other collections taken from off Port Credit, Ontario. It is probable, then, that the species is distributed along the shores of the entire lake.

BATHYMETRIC DISTRIBUTION

The only data available on the depth distribution of the species are derived from the use of special nets of 2½ and 2¾-inch mesh, which were set only between the depths of 20 and 75 fathoms at some time during the summers of 1921 and 1923, and from the examination of a few sets of 3-inch nets that are in commercial use for herring. Individuals occurred in the catches of these nets at depths of 20 to 65 fathoms. They were absent in the lift off Oswego, N. Y., made on September 4, 1923, in 70 to 75 fathoms, but occurred in lifts from off that port made in shallower water.

RELATIVE ABUNDANCE

The data from any of the nets show nothing conclusive about the relative abundance of the species, inasmuch as all the special sets were made with only the element of depth as a guiding factor, and it is well known that other factors influence the distribution of fishes. The data, however, seem to point to certain conclusions, which may be given more weight in that they agree with what is known about the habits of the species elsewhere.

No *reighardi* were taken in a special lift made off Bronte, Ontario, on June 29, 1921, in 40 to 50 fathoms; off Wilson, N. Y., on June 25, 1921, and July 16, 1921, in 50 fathoms, and off Oswego, N. Y., on September, 4, 1923, in 70 to 75 fathoms. Specimens of the species were rare in a lift made 8½ miles NNW. of Sodus Point,

N. Y., on July 12, 1921, in 60 fathoms (record 7); July 4, 1921, 7 miles off Braddock Point Light, N. Y., in 65 fathoms (record 8); June 23, 1921, 3 miles north of Wilson, N. Y., in 30 fathoms, and on July 19, 1921, 6½ miles N. by W. ½ W. of that port in 65 fathoms (records 9 and 10). Occasional specimens were taken in the special lift made on August 30, 1923, 14 miles west of Sandy Pond, N. Y., in 60 fathoms (record 4), and in the lifts of the commercial nets of 3-inch mesh made on July 11, 1921, 5 miles NNW. of Nine-Mile Point, N. Y., in 25 to 35 fathoms (record 5) and on August 24, 1923, 9 miles west of Sandy Pond, N. Y., in 25 to 30 fathoms (record 3). *Reighardi* occurred commonly in the lifts of the special nets made on June 10 and 16, 1921, 20 miles S. by W. of Presque Isle Light, Ontario, in 40 to 50 fathoms (records 1 and 2), on July 21, 1921, 2 miles north of Wilson, N. Y., in 20 fathoms (record 11), and also in the commercial 3-inch nets lifted on September 1, 1923, off Nine-Mile Point, N. Y., from 30 fathoms (record 6). (The occurrence of numerous examples of the species in the 3-inch nets is of particular significance, as only individuals of extreme size can be gilled in nets of such large mesh.)

The data from these sources thus indicate that the species is found most commonly at depths of 20 to 50 fathoms.

BREEDING HABITS

No breeding grounds of *reighardi* are known, nor can the time of spawning be established definitely. Of 6 female specimens sent me by Andrew Pritchard, of the University of Toronto, taken on February 12, 1926, off Port Credit, Ontario, 3 were spent, 2 were nearly ripe, and 1 was apparently a nonspawner. Mr. Pritchard, in a letter of January 8, 1927, says that in his experience spent fish are not common so early in the year. In April, 1926, most of the fish were nearly ripe, and a few started to spawn toward the end of the month. The main run, however, was in the first two weeks in May, when, according to the fishermen at Port Credit, the decks of their boats often were covered with spawn from the captured fish.

All but one of the fish taken at Brighton, Ontario, on June 10 and 16, 1921 (records 1 and 2), were either spent females or males from which milt could be squeezed. The exception was a female with loose eggs in the body cavity. Males taken at other ports later in that season not infrequently emitted milt or exhibited traces of pearls. The female showed eggs of the next season developing in the ovaries. The fish from Lake Ontario listed under *Leucichthys prognathus* as ripe or nearly ripe in May and June by Evermann and Smith (1896, p. 317) undoubtedly are of this species.

It appears, thus, that the spawning season for the species is probably in early May, certainly before June 10.

LEUCICHTHYS NIGRIPINNIS Gill

THE BLACKFIN (FIGS. 19, 20, AND 21)

Argyrosomus nigripinnis Gill, in Hoy, 1872, p. 99, Lake Michigan off Racine; Evermann and Smith 1896, pp. 317–320, pl. 27, Lake Michigan (probably not "lakes of Wisconsin and Minnesota").
Leucichthys nigripinnis Jordan and Evermann, 1911, pp. 26–27, Pl. IV, Lake Michigan (probably not "lakes of Wisconsin"); Dymond, 1926, pp. 62–63, Pl. III, Lake Nipigon.
Coregonus prognathus Smith, 1894, pp. 4–13, pl. 1, Lake Ontario.
Argyrosomus prognathus Evermann and Smith, 1896, pp. 314–317, pl. 26, Lake Ontario.
Leucichthys prognathus Jordan and Evermann, 1911, pp. 23–24, Lake Ontario.
Leucichthys cyanopterus Jordan and Evermann, 1911, pp. 27–28, fig. 13, Lake Superior off Marquette.

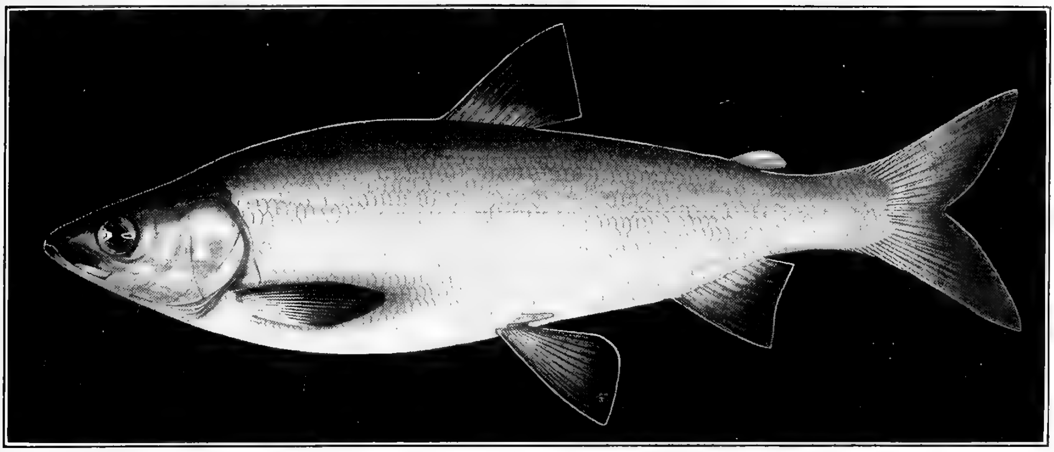

FIG. 19.—*Leucichthys nigripinnis* Gill, the blackfin. Male, 314 millimeters long, taken in Lake Michigan off Port Washington, Wis., in 60 to 80 fathoms on May 26, 1922

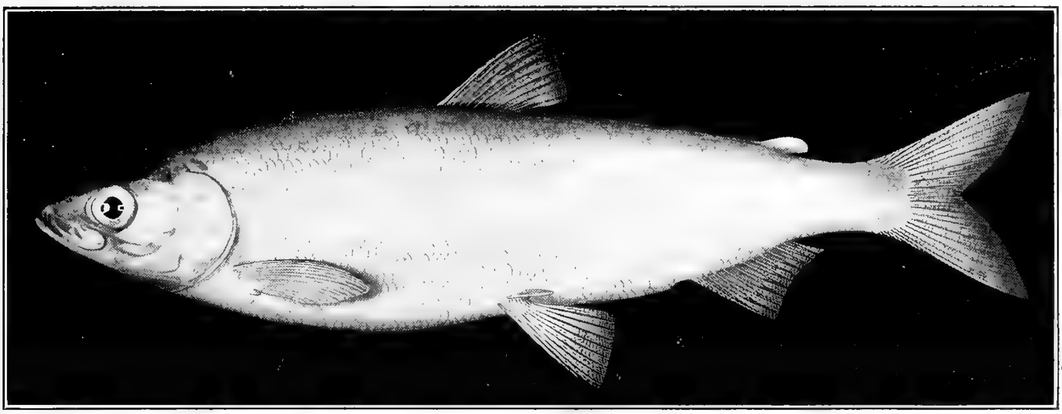

FIG. 20.—*Leucichthys nigripinnis cyanopterus* Jordan and Evermann, the bluefin. Male, 284 millimeters long, taken in Lake Superior off Michipicoten Island in 80 fathoms on June 22, 1922

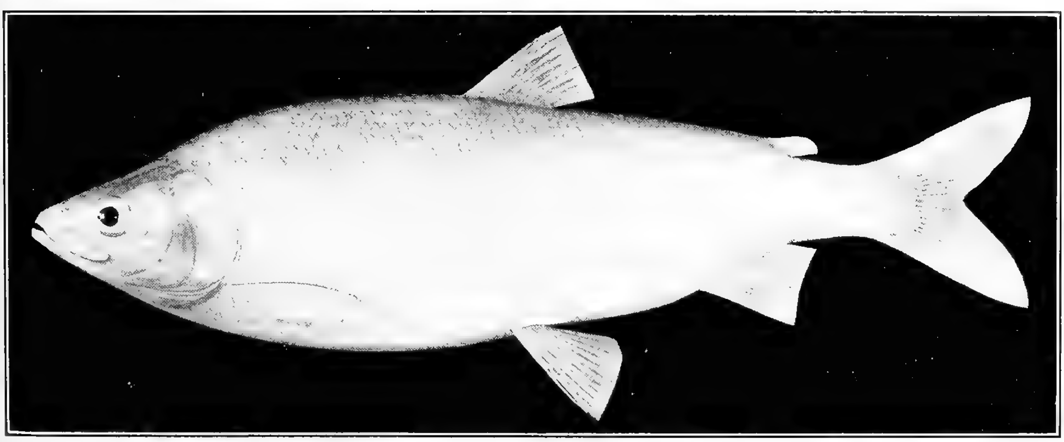

FIG. 21.—*Leucichthys nigripinnis prognathus* Smith, the bloater. Type, 297 millimeters long, taken in Lake Ontario

Leucichthys nigripinnis has been described from Lake Michigan and also has been recorded from Lakes Superior, Huron, Ontario, and Nipigon. In all the lakes it is distinguished by the large size it attains, its deep body (which is ovate in side view), and by its relatively long paired fins. In all but Superior and Ontario the species has conspicuously pigmented fins, and in all but Nipigon it inhabits by preference depths of 60 fathoms and more. The Huron form differs from the type form chiefly in having a larger head and eye, possibly fewer lateral-line scales, and slightly longer paired fins. The Superior form has fewer gill rakers, a longer head and snout, a smaller eye, less body depth, a shorter mandible, and paler fins than the typical form. In addition, it spawns in September as compared with December and January in the other Great Lakes. In Nipigon the form is distinguished chiefly by having slightly more gill rakers than the type, fewer lateral-line scales and scale rows, a larger head and eye, and longer pectorals. The fins are somewhat darker and the body paler. It frequents much shallower water and probably spawns about the same time as the Michigan form. The Ontario form probably was but little different from the typical race except that probably it was less pigmented. The race in Lake Nipigon has been designated *regalis* in this paper. The Lake Superior and Lake Ontario forms have been described as distinct species and called *cyanopterus* and *prognathus*, respectively. They are here regarded as subspecies.

Type

The type is no longer extant. The name is based on a specimen sent by Hoy to Gill, who named but did not describe it. The name is fixed by a cursory account published by Hoy in 1872.

Leucichthys nigripinnis nigripinnis of Lake Michigan

The blackfin is one of the largest of the deep-water Leucichthys. It not infrequently reaches a length of 35 centimeters (13¾ inches), with a weight of a little more than 1½ pounds, and nets of 3½ to 4 inch mesh were used to take it when it supported a fishery. The body is, in general, similar in shape to that of *johannæ*; as a rule, however, it is less elongate and slightly deeper. The depth is usually equal to 25 to 29 per cent of the total length. The width is about 47 to 52 per cent of the depth. At the occiput the dorsal profile rises rapidly to half the distance that separates the occiput from the dorsal. The remaining half of the contour line continues to the dorsal with only a slight upward trend. From the dorsal the contour continues ventrad and caudad in nearly a straight line to the adipose. The ventral profile, from the tip of the mandible to the ventral fins, runs like the opposite dorsal line. For the anterior half of this distance the line curves strongly downward and back ward, while the remaining half runs nearly parallel to the dorsal line and the linea lateralis. The portion of the body from the dorsal and ventrals to the head appears, therefore, to be of nearly uniform depth. As the depth increases the more vertical become the lines proceeding immediately from the occiput and the isthmus. From the ventrals the ventral contour line continues caudad and dorsad in a moderate curve. The head is moderate, broadly triangular as viewed from the side, and is contained (3.8) 4.1–4.4 (4.7) [78] times in the total length of the fish. The premaxil-

[78] These values and those given subsequently, unless indicated otherwise, are based on an examination of 52 specimens, which range in length between 220 and 360 millimeters.

laries usually are half as wide as long and make an angle of 45° to 60° with the horizontal axis of the head. Instead of a smooth curve connecting the tip of the snout with the occiput, as in the longjaw, where the premaxillaries occupy a similar position, the profile in the blackfin runs straight from the tip of the premaxillaries to their articulation with the rostroethmoidal cartilage and then continues in a faint curve to the occiput. The maxillary is pigmented and seldom extends much beyond the anterior edge of the pupil. The snout, viewed from the side, is deep and blunt and is contained 3.5–3.9 (4.1) times in the head length. The eye is large and is contained 4–4.4 (4.6) times in the total length of the head. The lower jaw usually is pigmented conspicuously and equal to or somewhat longer than the upper; occasionally, however, it is somewhat shorter. The gill rakers on the first branchial arch number (15) 16–19 + (26) 29–32 (34) = (41) 46–50 (52). Scales in the lateral line number (74) 80–87 (89). Scale rows around the body just in front of the dorsal and ventrals number (41) 42–44 (45);[79] just in front of the adipose and anus (32) 33–35 (36);[79] around the caudal peduncle (23) 24–26 (27).[79] Dorsal rays are 10–11;[79] anal rays (10) 11–12 (13);[79] ventral rays 11–12;[79] and pectoral rays (15) 16–17 (18).[80] The length of the pectoral fin is contained (1.5) 1.6–1.8 (2.2) times in the distance from the pectorals to the ventrals.

The distal half of the dorsal margin of the pectorals is usually decurved. The ventrals are contained 1.2–1.5 (1.6) times in the distance from their origin to that of the anal.

COLOR IN LIFE

The general tone is silvery, as in other Leucichthys, but in typical specimens the silvery cast is least conspicuous in this species on account of the heavy pigmentation. The entire dorsal surface is blue black, almost obscuring the pea green to blue green beneath. Below the lateral line a pale blue green is evident beneath the silvery layer. The sides and cheeks are suffused with a purplish iridescence, which is strongest above the lateral line. The maxillary and mandible are whitish, both more or less heavily pigmented. The fins also are whitish, all of them usually so heavily pigmented that the effect is also blue black.

In spirits the entire dorsal surface is more or less heavily pigmented, varying from dense pigment, giving an almost black effect in some individuals, to but scattered pigment in others. The top of the head is usually darker than the back, with the pigment here often concentrated in front of the nares. The tip of the mandible is dark, and the pigment of the back usually descends onto the sides of the head and body, sometimes with undiminished intensity on the operculum, postoculars, and in the preorbital area. The cranial margin and distal half of the dorsal fin, dorsal margin and distal half of the pectorals, distal half of the ventrals, distal half of the longer rays of the anal, and the lateral border and a broad band of the caudal are washed more or less with intense black. More or less of the fins may be pigmented, but the usual extent of the pigmentation has been given.

No blackfins were collected during the spawning season, but a male in the Field Museum collection, taken off Chicago, showed traces of pearls; and no doubt the males, at least, develop pearl organs, as do all other members of the genus in the basin.

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[79] Sixteen specimens.

[80] Twenty-six specimens.

VARIATIONS

Too few specimens are available for a study of local variations, and there is no material for a study of variation with growth, as none of the collected specimens are less than 220 millimeters in length. The smallest specimen collected measures 220 millimeters and is mature, but occasional much larger specimens in the collection are immature.

COMPARISONS [81]

Small blackfins bear a superficial resemblance to the kiyi, from which they may be distinguished by their more numerous gill rakers (which in the blackfin are seldom less than 44 and in the kiyi not usually more than 42) and by their more heavily pigmented fins, especially the ventrals, which are always more or less black in the former but usually immaculate in the latter. The blackfin has a wider body and thicker belly walls, a deeper and blunter head, and somewhat shorter paired fins. Females of the two species may be separated by the state of development of the ova. The blackfin spawns in late December and early January and the kiyi in October.

Only small *nigripinnis* could be confused with *hoyi*, as the former grows much larger. *Nigripinnis* is distinguished from *hoyi* by the body shape, which in the former is ovate, seen from the side, and in the latter elliptical; by the more numerous gill rakers on the first branchial arch and scales in the lateral line; and by the much darker coloration, particularly on the abdominal fins, which in the bloater are often immaculate and never conspicuously pigmented, while in the blackfin all of them are usually conspicuously black. The characters that can be expressed in figures are compared below:

Gill rakers on the first branchial arch:
- *nigripinnis*, (41) 46–50 (52), with 81 per cent more than 45.
- *hoyi*, (37) 41–44 (48), with 5 per cent more than 45.

Lateral-line scales:
- *nigripinnis*, (74) 80–87 (89), with 90 per cent more than 77.
- *hoyi*, (60) 67–77 (84), with 7 per cent more than 77.

The pectoral fins probably average a trifle longer in *nigripinnis*. The state of the sex organs also should serve often as a criterion in distinguishing at least questionable females, as *hoyi* spawns in March, *nigripinnis* in January. Individuals of *nigripinnis* under 200 millimeters in length probably would not be found often to be sexually mature, while *hoyi* are regularly mature as small as 140 millimeters.

Nigripinnis differs from *artedi* chiefly in the body shape, which is ovate in side view in the former and elliptical in the latter, and in the longer paired fins and greater body depth. The comparative figures for the last-named characters follow:

Pv/P:
- *nigripinnis*, (1.5) 1.6–1.8 (2.2), with 18 per cent more than 1.8.
- *artedi*, (1.6) 1.9–2.2 (2.6), with 94 per cent more than 1.8.

Av/V:
- *nigripinnis*, 1.2–1.5 (1.6), with 8 per cent more than 1.5.
- *artedi*, (1.4) 1.6–1.8 (2.3), with 89 per cent more than 1.5.

L/D:
- *nigripinnis*, (3.2) 3.4–3.9 (4.3).
- *artedi*, (3.6) 4.0–4.9 (5.3), with 62 per cent more than 4.3.

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[81] Figures given in this section for proportions are based on specimens 200 millimeters or more in length, except *artedi*, where he limit is 225 millimeters. Counts are given for specimens of all sizes.

Nigripinnis has also a much longer maxillary, a somewhat longer head relatively, and is more pigmented, especially on the paired fins, than the herring. The ventrals, particularly, are darker in *nigripinnis*.

Discussions of the differences between *nigripinnis* and *johannæ, alpenæ, zenithicus*, and *reighardi* are found on pages 352, 365, 389, and 402.

GEOGRAPHICAL DISTRIBUTION

My data on the occurrence of the blackfin in Lake Michigan are given in Table 40 and are shown platted on the chart in Figure 4. There are 20 records, all but 5 of them from personal observation on the commercial catches of the chub nets. A few individuals have been taken out of most of the ports visited, and the data indicate that the species may be found, at least occasionally, throughout the lake at suitable depths.

BATHYMETRIC DISTRIBUTION

The data in the aforementioned table are derived almost exclusively from an examination of the catches of the 2½ to 2¾ inch chub nets and from the testimony of fishermen. They show the blackfin to have been taken at depths of 30 to 90 fathoms. With the exception of the two lifts out of Michigan City on September 3 and October 11, 1920, in 30 to 40 fathoms (records 10 and 11), no individuals occurred in about 12 catches examined from nets lifted out of less than 40 fathoms, not including the sets on the spawning grounds of *zenithicus* and *hoyi*. None ever have been seen by me from either the 4 or 4½ inch trout and whitefish nets or the 1½-inch bait nets set usually at depths of less than 50 fathoms. (See p. 354.) The testimony of the fishermen, who undoubtedly know the blackfin, establishes its habitat in the deeper waters of the lake, and it is probable that the blackfin does not range outside of the 30-fathom contour. The outer limit of its range is not known.

RELATIVE ABUNDANCE

My observations on the abundance of the blackfin were made during the summer and fall of 1920 and in the summer of 1923 from an examination of the catches of the 2½ to 2¾ inch chub nets. Few chubs of any kind were taken in 1920. (See p. 354.) The fishermen, moreover, are unanimous in the opinion that blackfins are taken commonly only in nets of 3-inch or larger mesh, so that my observations show nothing conclusive on the present abundance of this species. (The small fish apparently do not consort with the largest ones and apparently not even with the other chubs. This does not seem to be true of the species in Lake Huron.) In each of the lifts made out of the following ports a few specimens were taken: Out of Washington Harbor, Wis., on August 19, 1920, 20 miles E. ½ N. of Rock Island in 71 to 90 fathoms (record 1); out of Sturgeon Bay, Wis., on August 23, 1920, 12 miles E. by S. of the ship-channel mouth in 60 to 70 fathoms (record 2); out of Port Washington, Wis., on September 25, 1920, 18 miles E. ½ S. in 65 to 48 fathoms, and on May 26, 1922, 24 miles E. by N. in 60 to 80 fathoms (records 3 and 4); out of Milwaukee, Wis., on March 24, 1919, in 50 fathoms, and on September 23, 1920, 27 miles ESE. in 60 fathoms (records 5 and 6); out of Michigan City, Ind., on September 3, 1920, and on October 11, 1920, 22 miles NW. by N. ½ N. and 20

miles N. by W. ¾ W. in 30 to 40 fathoms (records 10 and 11); out of Grand Haven, Mich., on March 20, 1919, 12 miles west in 50 to 55 fathoms (record 12); out of Ludington, Mich., on August 30, 1920, 17 miles W. ½ S. in 60 to 70 fathoms (record 13); out of Frankfort, Mich., on October 4, 1920, 9 miles north of Point Betsie in 60 to 70 fathoms (record 15); out of Northport, Mich., on June 22, 1920, and on July 31, 1923, 5 miles northwest of Cathead Light in 40 to 60 fathoms (records 16 and 17); out of Charlevoix, Mich., on June 30, 1920, 3 miles northwest in 40 to 65 fathoms and on August 11, 1923, 3 miles NW. ½ W. in 35 to 60 fathoms (records 18 and 19); and out of Manistique, Mich., on August 12, 1920, 15 miles SE. by S. ½ S. in 60 to 70 fathoms (record 20). All but the lifts out of Michigan City (records 10 and 11), it will be noted, were made, at least in part, from depths of 50 fathoms or more. In only one lift made at more than 50 fathoms were no blackfins observed, namely, out of Sheboygan, Wis., on October 1, 1920. It was absent in about 12 other lifts examined from nets set in less than 50 fathoms, the number not including those lifts made out of Milwaukee, Wis., and Michigan City, Ind., on the spawning grounds of *zenithicus* and *hoyi*.

My observations thus show that few blackfins were taken in the lifts examined during 1920 and that these were, for the most part, from nets lifted from depths of 50 fathoms or more. The early writers (Hoy, 1870; Milner, 1872) also had observed, or derived an opinion, that the blackfin was a fish of the deeper waters. If we turn to the testimony of the fishermen, we find that the species was formerly abundant in several localities, always at great depths. William Lahmann, a retired fisherman of Milwaukee, says that they were formerly abundant 40 miles ESE. of Milwaukee, Wis. (off Racine), in 80 to 90 fathoms, where they were caught while spawning in December and January (record 7). Cornelius Tamms, likewise of Milwaukee, states that he fished for blackfins with 3½-inch nets on these grounds from April to June (record 8). Charles Hyttel, sr., of Racine, who furnished the type specimen to Doctor Hoy, says that formerly he fished blackfins in 3½-inch nets off the city at depths of 60 fathoms and more. They spawned there, he says, in January (record 9). Peter and Hans P. Petersen, of Manistee, Mich, formerly fished blackfins 5 to 8 miles west of Manistee in 4⅛-inch nets at depths of 40 to 80 fathoms in December and January when the fish were spawning (record 14). Mr. Lahmann and the Petersens give 1905 as the year of a marked decline in the abundance of the species. Mr. Hyttel's tug records show occasional fair lifts in 1907, especially in January, but the records for succeeding years, including 1911, indicate takes of few blackfins.

BREEDING HABITS

Nothing is known from personal observation of the time or place of spawning. None of the specimens collected as late as October 4, 1920 (record 15), showed ripe eggs, and those taken as early as March 20, 1919, were spent. Thus the spawning season is some time between October and March. Observations of fishermen from several ports fix the time and indicate the location of at least two spawning grounds. Mr. Lahmann, of Milwaukee, and Mr. Hyttel, sr., of Racine, both have claimed to have taken the fish on their spawning grounds, 40 miles ESE. of Milwaukee, in 60 to 90 fathoms during late December and early January. The Petersens say that they

have taken them spawning at the same season 5 to 8 miles west of Manistee in 40 to 80 fathoms on clay. There are, or were, probably other spawning grounds in the lake.

Evermann and Smith (1896, p. 319) say that blackfins examined by them from off Sheboygan, Wis., taken about November 12 and 18, were "ripe or nearly ripe with spawn, * * * some were partially spent." These fish may have had prematurely developed gonads, as appears to happen frequently in the Great Lakes Leucichthys.

Leucichthys nigripinnis nigripinnis of Lake Huron

The Huron form resembles very closely the typical form. The chief characters may be compared at a glance:

Gill rakers on the first branchial arch:
- Michigan, (41) 46–50 (52).[82]
- Huron, (40) 46–50 (52).[83]

Lateral-line scales:
- Michigan, (74) 80–87 (89).
- Huron, (72) 77–83 (88).

L/H:
- Michigan, (3.8) 4.1–4.4 (4.7).
- Huron, (3.7) 4–4.2 (4.4).

H/E:
- Michigan, 4–4.4 (4.6).
- Huron, (3.6) 3.9–4.2 (4.6).

H/S:
- Michigan, 3.5–3.9 (4.1).
- Huron, (3.3) 3.4–3.8 (4.2).

Pv/P:
- Michigan, (1.5) 1.6–1.8 (2.2).
- Huron, (1.2) 1.4–1.7 (1.9).

Av/V:
- Michigan, 1.2–1.5 (1.6).
- Huron, (1) 1.1–1.4 (1.6).

It appears from the foregoing that the Huron form has, on the average, a larger head and eye and possibly fewer lateral-line scales and slightly longer paired fins.

The color of living fish is like that of the typical specimens. Specimens in spirits are also like those from Lake Michigan. The most noteworthy variation among individuals of the same school (and this has been observed most frequently in Georgian Bay) is the absence in some few examples of the characteristic bright blue body color and the reduction of the usual pigmentation of the fins, especially of the ventrals. These individuals differ from the rest in no other characters.

Males, at least, are known to develop pearl organs during the breeding season, but no examples in full breeding dress have been seen.

VARIATIONS

Racial variations.—The 71 specimens from Georgian Bay, compared in their principal characters with the 63 specimens from Lake Huron, virtually all taken off Alpena, Mich., do not show any differences to exist between the individuals of the two groups, except that the former may have a somewhat smaller eye.

Size variations.—All the collected specimens are over 200 millimeters in length, and most of them are over 250 millimeters in length, so that it is not possible to separate two groups of specimens for comparison according to size.

No specimen of blackfin smaller than 208 millimeters has been seen by me, and very few have been seen smaller than 230 millimeters. Specimens have not been found to be sexually mature under 220 millimeters.

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[82] All figures for Lake Michigan are based on an examination of 52 specimens, which range in length from 220 to 360 millimeters.

[83] All figures for Lake Huron are based on an examination of 134 specimens ranging in length from 208 to 371 millimeters.

COMPARISONS[84]

Nigripinnis resembles small *kiyi* and *artedi* most closely.

Small *nigripinnis* can be distinguished from *kiyi* probably only by the usual absence of black on the ventrals and the lighter pigmentation of the other ventral fins and by the fewer gill rakers, which in the former are (40) 46–50 (52) and in the latter (34) 36–40 (44), with 24 per cent more than 39. The state of development of ova in females might also serve to aid in separating the species at certain seasons, as *nigripinnis* spawns probably at least a month later than *kiyi*.

From *artedi*, *nigripinnis* is distinguished always by the body shape, as seen from the side, and the softer, more oily flesh. The body of the blackfin typically is deepest anteriorly, so as to be somewhat ovate in side view, and in the herring is more nearly elliptical. The common form of *artedi* has a smaller head and maxillary and shorter paired fins, but none of these differences hold for the Cutler race. A comparison of these characters follows:

L/H:
nigripinnis, (3.7) 4–4.2 (4.4).
artedi, (4) 4.3–4.6 (5), with 57 per cent more than 4.4.

H/M:
nigripinnis, (2.4) 2.5–2.6 (2.7), with 16 per cent more than 2.6.
artedi, (2.6) 2.8–3 (3.3), with 96 per cent more than 2.6.

Pv/P:
nigripinnis, (1.2) 1.4–1.7 (1.9), with 1 per cent more than 1.8.
artedi, (1.7) 2–2.2 (2.6), with 92 per cent more than 1.8.

Av/V:
nigripinnis, (1) 1.1–1.4 (1.6), with 1 per cent more than 1.5.
artedi, (1.4) 1.6–1.8 (2.1), with 90 per cent more than 1.5.

The fins of *nigripinnis* are, as a rule, much darker than of any *artedi* except those around Cutler. However, there is little occasion for confusing the two species in the field, as only stragglers of *artedi* are found off the shoals and *nigripinnis* is found rarely at depths of less than 60 fathoms.

Nigripinnis is compared with the other species of Leucichthys occurring in Lake Huron under the heading "Comparisons" in the accounts of these species.

GEOGRAPHICAL DISTRIBUTION

Table 42 contains all my data on the occurrence of the blackfin in Lake Huron. Figure 5 shows these data plotted on the chart of Lake Huron.

Lake Huron proper.—The records from the chub nets show the blackfin to occur in the same localities in the lake as do the other species of chubs. The same conclusion regarding distribution is warranted for this form, therefore, namely, that it ranges throughout the deeper waters of Lake Huron.

North Channel.—No specimens have been seen from the North Channel. The fishermen report chubs from this region (see p. 373), but they are not blackfins, according to these reports. Most fishermen are able to distinguish the blackfin from the other three species of chubs, and it is reasonably sure, therefore, that these reports are correct.

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[84] Figures given in this section are for all collected specimens except those of *artedi*, which are given for those specimens 225 millimeters or more in length, not including specimens of *manitoulinus*.

Georgian Bay.—Records 23 to 28 show the blackfin to occur with the other chubs in Georgian Bay at depths similar to those in which it occurs in Lake Huron.

From these data the conclusion may be reached that the blackfin occurs in the deeper waters of Lake Huron and Georgian Bay.

BATHYMETRIC DISTRIBUTION

There are no records of the occurrence of the blackfin in any of the net lifts examined by me from less than 35 fathoms. (See p. 374.) At depths of 35 to 100 fathoms it has been found by the chub nets. No catches were seen from more than 100 fathoms, but it is likely that the blackfin does occur beyond this limit, inasmuch as record 20 shows a huge haul of chubs from 80 to 100 fathoms, most of which were blackfins.

RELATIVE ABUNDANCE

At Cheboygan, Mich., on July 21, 1917, at Rogers, Mich., on July 24, 1917, and at Harbor Beach, Mich., on October 27, 1917 (records 1, 2, and 22), the specimens collected were the only ones seen. At all these ports the fishermen distinguish the blackfins from the other chubs, and all agree that the species is met rarely in their waters. On September 28 and 29, 1917, at Cheboygan, and on October 14, 1917, at Rogers, on the spawning grounds of *zenithicus* no blackfins were seen. Off Alpena, Mich., the tugs brought in blackfins more or less abundantly. From the center of the lake northeast of the can buoy, in 60 to 80 fathoms, on September 10, 1917 (record 5), September 14, 1917 (record 7), and September 17, 1917 (record 8); August 30, 1919, 18 miles N. by E. ½ E. from Thunder Bay Island (record 14); September 3, 1919, 28 miles E. ¼ S. from the can buoy in 60 to 64 fathoms (record 15); in 60 to 70 fathoms on August 7, 1920, 19 miles NE. ½ N., on June 30, 1923, 17 miles NE. by N. ¾ N., and on July 7, 1923, 13 miles NE. ½ N. of Thunder Bay Island (records 16, 18, and 21), blackfins comprised 5 to 24 per cent of the catches. From the center of the lake east of the can buoy in 65 to 80 fathoms on September 7, 1917 (record 4), September 12, 1917 (record 6), September 21, 1917 (record 9), September 24, 1917 (record 10), September 26, 1917 (record 11), October 17, 1917 (record 12), and October 20, 1917 (record 13), blackfins comprised 30 to 63 per cent of the catches. Three lifts made in 1923—on June 28, 19 miles northeast of Thunder Bay Island in 60 to 70 fathoms; July 2, 20 miles E. by N. of the can buoy in 60 to 70 fathoms; and on July 5, 18 miles NE. ¾ E. of Thunder Bay Island in 80 to 100 fathoms (records 17, 19, and 20), all lifts of over a ton—contained 75 to 90 per cent of blackfins. In Georgian Bay at Lions Head, Ontario, on July 30, 1919, only a straggler appeared in the haul made 21 miles east of Surprise Shoal in 60 fathoms (record 23). On October 6, 1919, off White Bluff in 70 fathoms most of the fish in a lift of 425 pounds were blackfins (record 24). On July 28, 1919, in a gang lifted off Cape Croker from 52 fathoms four blackfins were taken (record 26).

From all these data it appears that the blackfin is found in varying numbers in the chub lifts made at depths of 35 to 100 fathoms. Neither the 4½-inch, 1½-inch, nor the special 2¾-inch nets (see p. 374) have revealed it in less than 35 fathoms. From 35 to 50 fathoms few are taken in the chub lifts. The greatest proportion

occurs in lifts from 60 to 100 fathoms. The proportion is highest in those lifts from Lake Huron that were made in 1917 in the center of the lake east of Alpena and in 1923, 17 to 20 miles northeasterly from Thunder Bay Island, and in these lifts it may be as high as 90 per cent. In Georgian Bay the only lift in which blackfins were abundant was made from 70 fathoms. The blackfin thus seems to reach its maximum density at depths of 60 fathoms and more. This conclusion agrees with accounts of its habits in Lake Michigan.

BREEDING HABITS

It is not known that anyone has taken the fish on their spawning grounds in Lake Huron or Georgian Bay. From the condition of the ovaries of females examined as late as the middle of October, and from the occurrence of faint pearls on the row of scales below the lateral line in a single male taken at Lions Head, Ontario, on October 6, 1919, and one at Alpena on October 17, 1917, it appears that spawning does not take place before November. It may be deferred even until the last of December, as in the Lake Michigan form.

As in *johannæ,* some females often are taken which show undeveloped ovaries while the ova in the majority of the females of the species are approaching maturity. On September 21, 1917, out of 37 females examined 13 were nonspawning. (See p. 361.) These nonspawners ranged from 26 to 29 centimeters in length, the 24 spawners from 23 to 33 centimeters. On October 17, 1917, out of 43 females 12 were nonspawning and ranged from 25 to 29 centimeters in length; the remainder from 21.5 to 34 centimeters in length. On October 20, 1917, out of 41 females 11 were nonspawners of 26 to 31 centimeters and 30 were spawners 22.5 to 35 centimeters. The percentage of such sexually immature fish is too high to class the phenomenon as an abnormality, but an understanding of its significance must wait on knowledge of the rate of growth and age at maturity of the species.

FOOD

Stomachs have been examined from 56 individuals collected off Alpena, Mich., in September and October, 1917, and from two taken in Georgian Bay off Lions Head on October 6, 1919, all from depths of more than 60 fathoms. Mysis comprised almost the sole food of all specimens. In one or two stomachs a trace of plant fragments and of adult insects or a fish scale was found.

Leucichthys nigripinnis cyanopterus Jordan and Evermann, of Lake Superior

The Bluefin (Fig. 20)

The *nigripinnis* of Superior differs in many tehnical characters from the typical form, but the description of the body and its parts given for the type is applicable except as noted hereafter. The numerical expressions of the chief characters of the two forms are summarized for comparison chiefly from the data given in Tables 6 to 11.

Gill rakers on the first branchial arch:
- Michigan, (41) 46–50 (52).[85]
- Superior, (36) 38–42 (48).[86]

Lateral-line scales:
- Michigan, (74) 80–87 (89).
- Superior, (73) 79–86 (91).

L/H:
- Michigan, (3.8) 4.1–4.4 (4.7).
- Superior, (3.7) 3.9–4.2 (4.4).

H/E:
- Michigan, 4–4.4 (4.6).
- Superior, (4) 4.3–4.6 (5.2).

H/S:
- Michigan, 3.5–3.9 (4.1).
- Superior, (3.2) 3.4–3.7 (3.9).

Pv/P:
- Michigan, (1.5) 1.6–1.8 (2.2).
- Superior, (1.4) 1.6–1.8 (2.2).

Av/V:
- Michigan, 1.2–1.5 (1.6).
- Superior, (1.1) 1.3–1.5 (1.7).

$\frac{HD+AB}{M+S}$
- Michigan, (1.55) 1.75–1.85 (2).
- Superior, (1.45) 1.65–1.75 (1.85).

L/D:
- Michigan, (3.2) 3.4–3.9 (4.3).
- Superior, (3.2) 3.6–4.3 (4.6).

The most striking differences shown by these figures are the reduction in the number of gill rakers on the first branchial arch, the longer head and snout, the smaller eye, and less body depth in the Lake Superior specimens. In addition, the mandible, which is usually equal to or longer than the upper jaw in the typical form, is as often shorter as equal to the upper jaw and is but seldom decidedly longer.

This form was described by Jordan and Evermann (1909) as a new species. Their type is a specimen taken off Marquette, Mich. (No. 64672, U. S. National Museum). It is described in most of its characters in Table 45. The reasons for regarding it as a subspecies are discussed on page 331.

The color in life is less pronounced than in the Lake Michigan form, the coloration in general being not very different from that recorded for *zenithicus* of Superior. Preserved specimens of this race show less pigment, especially on the fins, than preserved specimens from Lake Michigan. The distal ends of the pectoral rays are paler, and the ventrals are immaculate in over 60 per cent of the specimens collected. Concentration of pigment in front of the nares is less frequent in the Lake Superior specimens.

Males and at least some females develop pearl organs in the breeding season. Pearled individuals were collected off Grand Marais, Mich., on October 3, 1917, and off Rossport, Ontario, on October 4, 1921. The development of nuptial excrescences is much like that described for *johannæ* on page 350.

VARIATIONS

Racial variations.—There are too few specimens from any locality for a study of local variations. The specimens at hand, however, grouped according to locality, do not indicate any marked difference between the groups.

Size variations.—There is only one specimen smaller than 200 millimeters, so that juveniles can not be compared with adults. Sixty-six specimens 30 centimeters and more in length, when compared with 102 smaller individuals, showed only a somewhat shorter head, smaller eye, greater depth, and shorter paired fins:

[85] These and other figures for Lake Michigan are based on an examination of 52 specimens ranging in length from 220 to 360 millimeters.

[86] These and succeeding figures for Lake Superior are based on an examination of 168 specimens ranging in length from 198 to 375 millimeters.

COMPARISONS[87]

The bluefin can be confused only with *zenithicus*. A discussion of the differences between these species may be found on page 380. An account of the differences between *nigripinnis* and *reighardi* is given on page 411.

Only small examples can be confused with *hoyi* and *kiyi*, as the latter do not grow large. There are too few *nigripinnis* of a size comparable with these species for contrasting of characters affected by growth. Small *nigripinnis* may be distinguished from both by the shorter mandible (which seldom is distinctly superior in this form), the thicker belly walls, and the more decurved dorsal margin of the pectorals. They may be separated further from *hoyi* by the more numerous lateral-line scales, which in *nigripinnis* number (73) 79–86 (91), with 87 per cent more than 78, and in *hoyi* (65) 69–78 (84), with 7 per cent more than 78; by the smaller average number of gill rakers on the first branchial arch; the greater average number of scale rows; and by the less elliptical body outline, as viewed from the side. The paired fins of small *nigripinnis* probably will be found to average considerably shorter than those of *kiyi*.

From *artedi*, *nigripinnis* usually is separable by its softer, more oily flesh; the body shape, which is ovate, as seen from the side, as compared with the elongate elliptical form in *artedi*; its fewer gill rakers on the first branchial arch; and by its longer paired fins, head, and maxillary. Some of these characters are compared fully below:

Gill rakers on the first branchial arch:
artedi, (41) 45–48 (53), with 87 per cent more than 44.
nigripinnis, (36) 38–42 (48), with 2 per cent more than 44.

L/H:
artedi, (4.1) 4.3–4.6 (5.1), with 80 per cent more than 4.3.
nigripinnis, (3.7) 3.9–4.2 (4.4), with 2 per cent more than 4.3.

H/M:
artedi, (2.5) 2.7–3 (3.1), with 70 per cent more than 2.7.
nigripinnis, (2.3) 2.5–2.7 (2.8), with 3 per cent more than 2.7.

Pv/P:
artedi, (1.7) 2–2.2 (2.8), with 84 per cent more than 1.9.
nigripinnis, (1.4) 1.6–1.8 (2.2), with 5 per cent more than 1.9.

Av/V:
artedi, (1.3) 1.6–1.8 (2.3), with 91 per cent more than 1.5.
nigripinnis, (1.1) 1.3–1.5 (1.7), with 6 per cent more than 1.5.

L/D:
artedi, (3.7) 4.3–5 (5.9), with 80 per cent more than 4.3.
nigripinnis, (3.2) 3.6–4.3 (4.6), with 5 per cent more than 4.3.

In addition, *nigripinnis* has, on the average, the margin of the pectoral more decurved, a longer snout, and fewer lateral-line scales. It spawns in September, while *artedi* spawns in late November, so that the state of development of the sex organs also may aid in separating specimens of the two forms.

GEOGRAPHICAL DISTRIBUTION

Data on the occurrence of the bluefin in Lake Superior, which are presented in Table 44 and shown platted on the chart in Figure 3, have been derived, for the most

[87] Figures given in this section for proportions are for specimens chiefly over 225 millimeters in length. Counts are given for specimens of all sizes.

part, from the use of special 2½ and 2¾ inch nets set out of various ports on the lake and are supplemented by the testimony of various fishermen. These records, 26 in number, show that the bluefin formerly was taken in commercial quantities out of many ports on the lake and that they still occur, if only sparingly, in suitable areas of the lake.

BATHYMETRIC DISTRIBUTION

The special nets used in the survey of the lake, which were set at depths of 15 to 100 fathoms (see p. 382), took at least one specimen of *nigripinnis* at every set excepting one set off Ontonagon, Mich., and those sets made in 1923 in the bays and straits along the north shore. A few specimens also have been found in the 4½-inch nets set along the shore banks (records 10, 15, 18, 22, and 25). It is certain, therefore, that a few individuals, at least, stray into the shallower waters. The records do not indicate the maximum depths at which the species occurs, but the testimony of the commercial fishermen who at one time fished for the species establishes 100 and 110 fathoms as the greatest depths at which nets were set. The general chart of Lake Superior shows that much of its area is overlaid by more than 100 fathoms of water (a depth of 196 fathoms is known), but the fishermen do not set nets at greater depths on account of the strain on them in lifting and on account of the effect of the extreme pressure on their floats. It is safe, however, to predict that if fish were abundant in the deepest water, the nets would be placed there, and it is certain, therefore, that the center of abundance of the bluefin is or was in less than 100 fathoms. There are various conjectures as to what may inhabit the deepest waters, but there are few data on that point. Mr. Parker, of Marquette, informs me that once, northwest of Stannard Rock, his gang of 4½-inch trout nets fell into a hole that flattened the corks on half a mile of his netting and that these nets caught no other fish than the lawyer (*Lota maculosa*), but that the lawyer was abundant. (The chart shows a maximum sounding of 115 fathoms for this area, though a greater depression of small extent might occur easily.)

One may conclude from the foregoing that the bluefin ranges from 15 fathoms into more than 100 fathoms, but that the maximum density is to be looked for nearer the upper limit.

RELATIVE ABUNDANCE

In none of the lifts did the bluefin occur more than casually, but it is possible that the nets employed were of too small mesh to take the fish. The fishermen in Superior found that nets could not take bluefins in commercial quantities if they were of smaller mesh than 3¼ inches, and the experience of Michigan and Ontario fishermen has been the same for the *nigripinnis* of these lakes. It would appear that the smaller individuals of the species did not school with the largest examples or kept farther above the bottom. In lifts made from gangs extending into less than 60 fathoms, off Iroquois Light on June 14, 1922, in 38 fathoms (record 1), off Marquette, Mich., on August 8, 1921, in 42 to 65 fathoms (record 5), off Ontonagon, Mich., on August 25, 1921, in 20 to 38 fathoms (record 11), among the Apostle Islands on July 11, 1922, in 15 to 20 fathoms (record 13), off Duluth, Minn., on July 17, 1922, in 30 to 40 fathoms (record 16), and off Grand Marais, Minn., on September 14, 1921, in 30 to 65 fathoms (record 17), bluefins made up not more than 3 per cent of

the catches, and the sets showed a maximum of 0.5 fish per night per thousand feet of net. When the gangs extended from 60 fathoms to greater depths bluefins were less rare. Lifts made off Marquette, Mich., on August 11, 1921, in 100 to 80 fathoms (record 6), off Rossport, Ontario, on October 4, 1921, in 80 to 90 fathoms (record 20), off Michipicoten Island, Ontario, on June 22, 1922, in 80 fathoms (record 23), and off Alona Bay, Ontario, on June 26, 1922, in 60 fathoms (record 26), showed from10 to 21 per cent of bluefins and from 1 to 6 fish per night per thousand feet of net. The records from the 4½-inch trout nets in 60 fathoms and deeper (records 2 and 4) show 25 and 10 specimens per gang, while those in or bordering on shallow water (records 10, 14, 15, 18, 22, and 25) took from 1 to 6 specimens per gang.

My findings that the bluefin prefers depths of more than 60 fathoms are corroborated by the statements of fishermen who over a period of years fished bluefins exclusively out of Grand Marais, Marquette, and Ontonagon in Michigan, Grand Marais in Minnesota, and off Michipicoten Island in Ontario (records 3, 9, 12, 19, and 24). These men all agree that the species occurred most abundantly throughout the fishing season, which extended from April to November, between 60 and 100 or 110 fathoms.

Whatever factors determine the vertical distribution of the bluefin, it is clear that temperature is not the only one, unless it be that the species prefers to inhabit a zone of practically constant temperature, such as probably obtains along the bottom in the deeper waters. The data in Table 13 indicate that in mid-June and up to July the bottom waters to a depth of at least 25 fathoms are not warmer than 4°, the temperature of the maximum density of water, and may be even colder. During August, though the thermocline appears to be relatively near the surface, there is evident a slight effect of warming down to 54 fathoms. In 60 fathoms and deeper there is probably no warming above 4°. The bluefins seldom are taken shallower than 60 fathoms and may spend their lives in water of nearly constant temperature, little influenced, at least directly, by the seasonal temperature fluctuations that affect the upper layers of the water.

It has been intimated in the preceding discussion that the bluefins are no longer of commercial significance in Lake Superior, but it once occurred there abundantly. It has been possible to record some facts of their history, which the various fishermen who were at one time engaged in fishing them have been able to supply from memory. Definite dates given in the testimony have been fixed by association with significant events in the life of the narrator and have been accepted without further research. The first bluefins on the American shore, so far as I can learn definitely, were taken out of Ontonagon, Mich., about 1897. They are recorded in the statistics of the Bureau of Fisheries for that year. The Booth Fisheries Co., according to two of its pilots (McArthur and McMillan), began to take the fish out of Michipicoten Island about 1900. Out of Marquette, Mich., a fishery was started by W. J. Parker in 1901. At Grand Marais, Minn., James Scott first fished them in 1903. They were produced out of other ports at about the same time, but no definite dates are available.

For several years the bluefins supported a lucrative fishery. The tugs, in a gang of the 3¼ to 3¾ inch nets, which were used exclusively, often made hauls of 2 or 3 tons; but, strange enough, the fish ceased to be economically important at about

the same time out of all the ports. The Booth Co. discontinued its small-meshed nets in 1903; but the fish were not gone then, because they are said to have been taken abundantly in the 4½-inch ciscowet nets for a few succeeding years. Mr. Scott says that in 1906 they were noticeably scarcer than in the preceding years, but that they could still be taken in paying quantities. Mr. Parker states that in the fall previous to their disappearance they were still fairly numerous, but that there were none in the following spring. They seem to have been taken last out of Ontonagon and Grand Marais, Mich., but since about 1907 no industry has depended on the bluefin alone.

It is not certain what factors contributed to bring about the decline of the species. Unless most of the individuals of the species do not become sexually mature until they attain a length of 10 inches, it is strange that intensive fishing should have affected their abundance so soon. The nets employed would hardly take a fish of smaller size, and in theory it appears judicious to permit the use of a mesh that will take only the largest examples of the species. Furthermore, there were vast areas, especially along the Canadian shore, in which the bluefins were not exploited, and it would be expected that the lake would be restocked from the surplus of these areas if overfishing alone were responsible for their decrease. Latterly no bluefin nets have been tried, and it would be interesting to know if the bluefins are becoming more abundant on the American side and if they occur in their original abundance on the Canadian shore. I have pointed out already in various connections that the nets I used in the survey of the Leucichthys fauna of the lake were too few, probably of unsuitable mesh, and necessarily were employed too much at random to give conclusive results on the present status of the species.

BREEDING HABITS

Pearled males and females spent, spawning, or nearly ripe were collected out of Grand Marais, Mich., on October 3, 1917, in 65 fathoms and deeper (record 2) and out of Rossport, Ontario, on October 4, 1921, in 80 to 90 fathoms (record 20). It is not possible to state, of course, that the nets in either case were lifted from the spawning grounds of the species, but the state of development of the sex organs of the individuals taken indicates, at least approximately, the time of spawning and furnishes corroboration of the statements of the fishermen who once fished for the species. Mr. Parker and Mr. McLean, of Marquette, Mich., and Mr. Scott, of Grand Marais, Minn., state that the bluefins spawned during September on the grounds they frequented during most of the year at depths of 60 to 100 fathoms. Mr. Desjardins and Mr. Macdonald, of Grand Marais, say that the bluefins were most abundant out of that place in September, which would indicate that there was also a spawning run at that time out of that port.

Leucichthys nigripinnis regalis (new subspecies) of Lake Nipigon

The Nipigon blackfin is like the typical form in respect to body shape and general appearance. The main differences are numerical, and the values for certain characters are summarized below for comparison:

Gill rakers on the first branchial arch:
Michigan, (41) 46–50 (52).[88]
Nipigon, (44) 48–51 (54).[89]
Lateral-line scales:
Michigan, (74) 80–87 (89).
Nipigon, (66) 70–77 (81).
L/H:
Michigan, (3.8) 4.1–4.4 (4.7).
Nipigon, (3.6) 3.8–4.1 (4.4).
H/E:
Michigan, 4–4.4 (4.6).
Nipigon, (3.5) 3.7–4.1 (4.3).
H/S:
Michigan, 3.5–3.9 (4.1).
Nipigon, (3.4) 3.6–3.8 (4.3).
Pv/P:
Michigan, (1.5) 1.6–1.8 (2.2).
Nipigon, (1.2) 1.4–1.6 (1.9).
Av/V:
Michigan, 1.2–1.5 (1.6).
Nipigon, (1.1) 1.2–1.5 (1.7).
L/D:
Michigan, (3.2) 3.4–3.9 (4.3).
Nipigon, (3.1) 3.5–4 (4.5).

The figures indicate that the Nipigon form has, on the average, somewhat more gill rakers on the first branchial arch, many less scales in the lateral line, a larger head and eye, and longer pectorals. In addition to fewer scales, there are also, on the average, two less scale rows, so that around the body in front of the dorsal and ventrals there are usually 40 to 42 [90] rows, in front of the adipose and anus 31 to 33,[90] and around the caudal peduncle at its commencement 22 to 23.[90] The dorsal margin of the pectoral is usually straight instead of decurved. Comparison of specimens in Tables 41 and 47 shows a greater value in Nipigon specimens for the height of the anal fin divided by its base length (AC).

The race appears to be sufficiently distinct to merit designation, and I propose to name it *regalis*. Specimen No. 57416 of Table 47 is designated as the type. It is catalogued in the United States National Museum as No. 88354.

The color in life is similar to that of the typical race, except that the back is not pigmented so heavily and the underlying color is therefore less obscured. All the fins are invariably conspicuously black; the membranes have a trace of sepia, strongest at the bases and becoming pinkish at the bases of the abdominal fins. In spirits specimens seem to average blacker on the fins than the Lake Michigan specimens.

Pearl organs probably are developed by the breeding males, but no specimens taken in the breeding season have been examined.

VARIATIONS

No specimens are available for the study of local variations. Only six specimens smaller than 200 millimeters have been examined, and most of these are so imperfect that their proportions have not been tabulated. The two of this class that have been included in Table 47 show the same kind of differences when compared with longer specimens, as the group of 151 specimens 200 to 290 millimeters in length compared with 69 over 290 millimeters long. The first group showed, on the average, a slightly larger head and eye, slightly longer paired fins, and less body depth than the longest fish.

Specimens smaller than 230 millimeters in length have been found to be sexually immature, and often specimens 250 millimeters long were immature.

[88] These and other values given for Lake Michigan are based on an examination of 52 specimens ranging in length between 220 and 360 millimeters.

[89] These and succeeding figures for Lake Nipigon, unless marked otherwise, are based on an examination of about 230 specimens ranging in length from 204 to 355 millimeters.

[90] Twenty-six specimens.

94995—29——10

COMPARISONS [91]

Nigripinnis regalis approaches most closely *nipigon*. The chief differences are in the number of gill rakers on the first branchial arch, which in the former are not known to number more than 54 and in the latter not less; in the body shape, which is usually strongly ovate in side view in the former and elliptical in the latter; and in the relative size of the eye as compared with the head. The value of H/E for *nigripinnis* is (3.5) 3.7–4.1 (4.3) and for *nipigon* (3.8) 4.4–4.6 (5.2), with 71 per cent more than 4.3. The blackfin is pigmented much more heavily as a rule, especially on the abdominal fins.

A discussion of the difference between *nigripinnis* and *zenithicus* and *reighardi* is given on pages 386 and 407.

Only small *nigripinnis regalis* are comparable with *hoyi*, as *hoyi* does not attain great size. The two species are always distinguishable by the more ovate body shape of the former, by the much heavier pigmentation of body and fins and by the greater number of gill rakers on the first branchial arch, which in *nigripinnis* number (44) 48–51 (54), with 68 per cent more than 48, and in *hoyi* (40) 42–46 (48).

Nigripinnis regalis differs from *artedi* in body shape, which is ovate in side view in the former and elliptical in the latter; in the longer paired fins and maxillary, and the deeper body, as is indicated by the following figures:

Pv/P:
- *nigripinnis*, (1.2) 1.4–1.6 (1.9), with 33 per cent more than 1.5.
- *artedi*, (1.5) 1.6–1.8 (2), with 96 per cent more than 1.5.

Av/V:
- *nigripinnis*, (1.1) 1.2–1.5 (1.7), with 7 per cent more than 1.5.
- *artedi*, (1.3) 1.5–1.6 (1.7), with 47 per cent more than 1.5.

H/M:
- *nigripinnis*, (2.4) 2.5–2.6 (3), with 14 per cent more than 2.6.
- *artedi*, (2.5) 2.7–2.8 (3), with 87 per cent more than 2.6.

L/D:
- *nigripinnis*, (3.1) 3.5–4.0 (4.5), with 10 per cent more than 4.
- *artedi*, (3.8) 4.1–4.6 (5), with 88 per cent more than 4.

Artedi is also less pigmented, especially on the paired fins, which are never conspicuously black as in *nigripinnis*.

GEOGRAPHICAL DISTRIBUTION

All the records of specimens taken by me and of those examined from the University of Toronto collection are given in Table 46 and are shown platted on the lake chart in Plate 2. They show that the species has been taken in each of the three lifts of the 2½ and 2¾ inch nets made by me and that individuals also have been obtained from numerous other localities, even in the commercial whitefish nets. It is probable, then, that the species occurs throughout the lake where suitable conditions obtain.

BATHYMETRIC DISTRIBUTION

My records show that the species was taken commonly on July 25, 1922, in 10 to 15 fathoms off the source of the Nipigon River, but more abundantly July 26,

[91] The specimens compared in this section for proportions are those 200 millimeters or more in length, except *artedi*, which are 225 millimeters or more. Counts are given for specimens of all sizes.

1923, in 30 fathoms off Macdiarmid (records 19 and 2). The relative abundance of this and other species of Leucichthys in these two lifts is given on page 409. In the lift made on July 28, 1922, in 56 fathoms, 2½ miles south of Livingston Point, only three specimens were taken, though the same kind and about half the quantity of netting was used as on the other two dates (record 6).

John McIver, Mr. Walsh, and Mr. McKay, who have fished on the lake for several years, state that the species is taken in their 4½-inch whitefish nets most commonly in 20 to 40 fathoms throughout the fishing season. The moon-eye, as the fishermen term the fish, evidently is common in Lake Nipigon, but no nets designed to take it for commercial purposes are employed.

BREEDING HABITS

It is not known when or where the species spawns. None of the specimens obtained on October 26, 1922, at the close of the commercial fishing season on the lake (record 24) showed mature sex organs. The spawning time is probably in winter.

Leucichthys nigripinnis prognathus Smith, of Lake Ontario

I have been able to find no other specimen, either by search in museums or by exploration in Lake Ontario, than the type specimen of Smith 297 millimeters long (No. 45568, U. S. National Museum). The catalogue gives no date or locality other than "Lake Ontario."

The specimen is figured in Figure 21, and certain proportions and counts of multiple parts are given in Table 45. In body shape it agrees closely with the typical blackfin. It is much less pigmented throughout than any known race of blackfin. The abdominal fins are immaculate, or nearly so, and the caudal has only an indication of black on the tips of the rays. The maxillary is pigmented. The mandible is about equal in length to the upper jaw.

GEOGRAPHICAL DISTRIBUTION

Only the statements of the fishermen give any clue to the former distribution of the species in the waters of Lake Ontario. It is inferred from their accounts of a fish attaining large size, inhabiting deep water, and spawning in early winter that this fish was *prognathus*. From this testimony it appears that the fish was taken commonly out of various ports on the south and west shores of the lake. The species probably was distributed throughout the deep waters.

BATHYMETRIC DISTRIBUTION

The fishermen say that the best bloater fishing was at depths of 60 fathoms and more, though at times, at least, smaller quantities could be taken near shore.

ABUNDANCE

I quote Koelz (1926, p. 606) on the history of the species:

> The first fishery for bloaters was carried on out of Oswego about 1875. A fisherman operating out of that port found a few individuals in the outer ends of his whitefish gangs and conceived the idea that it might be profitable to fish them. The fish were sold fresh and were so much in demand that at one time there were several boats engaged exclusively in bloater fishing out of that port.

The industry gradually spread to the westward, and by 1890 bloaters were being taken out of Wilson. At first they were extremely abundant, and it was never necessary, in American waters, to use a net of smaller mesh than 3 inches, and usually the mesh employed was 3½ inches, but before 1900 the bloater was commercially exterminated, and efforts to revive the industry since then have met with absolute failure. Repeated efforts to locate these fish, made by me in the summers of 1921 and 1923, failed, and not a single specimen was found, so that it appears likely that the species is extinct. No cause for its extermination suggests itself. At no time were any but the largest examples of the species taken, and so far as known it had no important vertebrate enemies. The case has close parallels in the related blackfin of Lake Michigan and the bluefin in Lake Superior, which suddenly became commercially insignificant, though not extinct, under identical conditions.

BREEDING HABITS

George Jones, of Sodus Point, N. Y., and Paul Methot, of Oswego, N. Y., who claim to have fished bloaters longest, state that the fish moved somewhat shallower, to depths of 40 to 50 fathoms, in the spawning season. They spawned in January.

LEUCICHTHYS KIYI Koelz

THE KIYI (FIG. 22)

Leucichthys kiyi Koelz, 1921, Lakes Michigan, Huron, and Superior.

Leucichthys kiyi has been described from Lake Michigan and is known to occur also in Lakes Superior, Huron, and Ontario. It is characterized everywhere by its relatively small size (the individuals of Superior and Huron appear to be especially dwarfed and seldom have been seen larger than 20 centimeters), thin body (which is ovate in side view), and relatively long paired fins. It everywhere prefers deep water and usually is found at depths of 60 fathoms or more. The Superior form differs from the type form chiefly in attaining less size, in having somewhat fewer scales in the lateral line, longer pectoral fins, and possibly an average larger head and eye. It spawns in late November, also, as compared with October, which is the supposed spawning time for the Michigan form. The Huron race differs from the typical race chiefly in that it appears seldom to grow so large. The spawning time in Huron in unknown, but it seems to be somewhat later than in Michigan. Ontario specimens differ most of all from those of Michigan, and the Ontario race has been designated here *orientalis*. They have many more gill rakers on the first branchial arch, much shorter paired fins, and a somewhat shorter head. The spawning season in Ontario apparently falls in August.

The type is a female specimen (catalogue No. 84100, U. S. National Museum), 191 millimeters in length to the base of the caudal, collected in Lake Michigan on August 23, 1920, 12 miles E. by S. of the mouth of the Sturgeon Bay ship channel in 60 to 70 fathoms of water.

Leucichthys kiyi kiyi of Lake Michigan

The kiyi is one of the smallest chubs. Extreme examples selected from hundreds of specimens in the field measure only 245 millimeters. The fish are thin as well as small and therefore are not esteemed by the fish smokers. The body is fusiform, slightly more compressed than in other members of the genus, and, as in *johannæ* and *nigripinnis*, its only associates of the deeper waters, the depth is distinctly greatest in front of the dorsal fin. This dimension in the type specimen com-

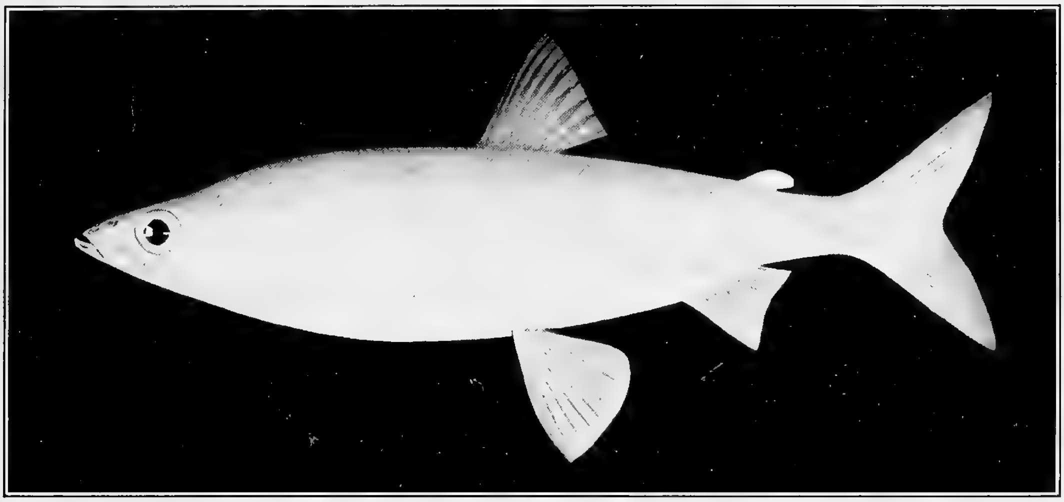

FIG. 22.—*Leucichthys kiyi* Koelz, the kiyi. Female (type), 191 millimeters long, taken in Lake Michigan off the Sturgeon Bay ship channel mouth in 60 to 70 fathoms on August 23, 1920

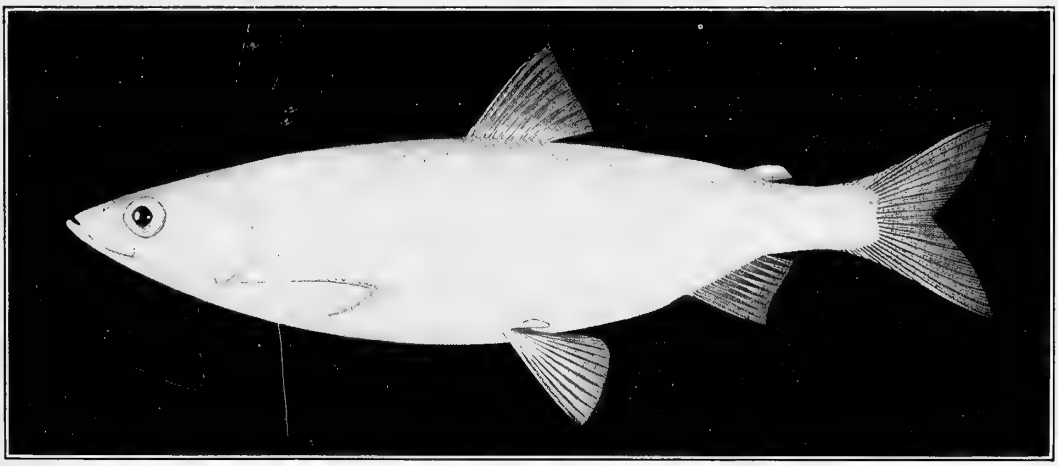

FIG. 23.—*Leucichthys hoyi* Gill, the bloater. Male, 206 millimeters long, taken in Lake Michigan off Milwaukee, Wis., in 50 fathoms on March 24, 1919

prises 24 per cent of the body length. At the occiput the dorsal profile rises in a smooth curve over half the distance to the dorsal and continues to the dorsal with only a slight upward trend. From the dorsal the contour slopes gently to the caudal peduncle. The ventral profile from the tip of the mandible to the ventral fins runs like the opposite dorsal contour, curving strongly downward and backward for two-thirds its extent and extending to the ventrals over its remaining one-third in a line nearly parallel to the lateral line. From the ventrals to the anal the contour converges distinctly toward the lateral line. The head is rather elongated and is contained 4 [(3.7) 3.8–4.1 (4.3)] [92] times in the total length.

Its dorsal profile runs in a faint but distinct convex curve to a point above the center of the orbit and from thence to the occiput is often more or less concave in its course. The premaxillaries are directed forward and make an angle of about 50° with the horizontal axis of the head. The snout is always longer than the large eye, which is contained 3.9 [(3.6) 3.8–4.2 (4.3)] times in the head. The maxillary is pigmented and extends beyond the anterior edge of the pupil but never to its center. The mandible is rather frail and usually projects beyond the upper jaw. Seldom is it shorter. The gill rakers on the first branchial arch are relatively short; they number 15+25 [(11) 13–15 (17)+(21) 23–26 (27)=(34) 36–41 (45)].[93] The scales in the lateral line number 85 [(71) 77–87 (91)]; 82 per cent of all the specimens examined have 79 or more scales. Rows of scales around the body just in front of the dorsal and ventrals number 46 [(39) 41–44 (46)]; [94] just in front of the adipose and anus 37 [(32) 33–35 (37)]; [94] around the caudal peduncle at its commencement 26 [(23) 24–25 (26)].[94] The dorsal rays are 10 [9–10 (11)]; [95] the anal rays 11 [(9) 10–12 (16)]; [96] ventral rays 11 [11–12]; [94] pectoral rays 15 [(15) 16–17 (18)].[94] The dorsal margin of the pectoral is usually straight. The pectorals are contained in the distance from their insertion to that of the ventrals 1.6 [(1.1) 1.4–1.7 (2.1)] times. The ventral length divided into the distance from their origin to the insertion of the anal equals 1.2 [(0.96) 1–1.3 (1.4)].

The color in life is about like that of *johannæ*. The underlying color is obscured in the back by the dense pigmentation, which covers nearly uniformly the entire dorsal surface and which also extends over the entire preorbital area, including all but about the distal one-fourth of the maxillary. The dorsal surface of the head in front of the nostrils, likewise the tip of the mandible, are often very dark. Pigment occurs, too, on the sides, abundantly above but only sparsely below the lateral line. The dorsal and caudal fins are rather widely margined with black, most intensely on the median rays of the caudal. The dorsal margin of the pectorals often is lined with black, and the membranes of the anal are frequently sparingly sprinkled with pigment. The ventrals are usually immaculate. In spirits the color fades, leaving obvious the details of pigmentation.

Pearl organs are developed by at least the breeding males, as evidenced by the taking of specimens showing incipient pearls; but no breeding fish have been examined by me.

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[92] The figures in brackets, unless otherwise marked, are given for 174 examined specimens, 120 of them paratypes, which range in length from 122 to 245 millimeters.

[93] Two hundred and twelve specimens.

[94] Twenty-two specimens.

[95] One hundred and fifty-four specimens.

[96] One hundred and forty-four specimens.

VARIATIONS

There are not enough specimens in my collection for a study of local variation, and the examples in the collection are too nearly uniform in size to yield data on changes with growth.

COMPARISONS [97]

Kiyi resembles *nigripinnis* and *hoyi* more closely than any other Leucichthys of the lake. It is contrasted with the former on page 419. It differs from *hoyi* in body shape (which is rather ovate in side view in *kiyi* and elliptical in *hoyi*), in the fewer gill rakers on the first branchial arch, more lateral-line scales, and longer paired fins. The last-mentioned characters are compared below:

Gill rakers on the first branchial arch:
- *kiyi*, (34) 36–41 (45), with 14 per cent more than 40.
- *hoyi*, (37) 41–44 (48), with 86 per cent more than 40.

Lateral-line scales:
- *kiyi*, (71) 77–87 (91), with 88 per cent more than 77.
- *hoyi*, (60) 67–77 (84) with 7 per cent more than 77.

Pv/P:
- *kiyi*, (1.1) 1.4–1.7 (2.1), with 13 per cent more than 1.7.
- *hoyi*, (1.3) 1.7–2 (2.5), with 74 per cent more than 1.7.

Av/V:
- *kiyi*, (0.9) 1–1.3 (1.4), with 1 per cent more than 1.3.
- *hoyi*, (1) 1.2–1.4 (1.7), with 33 per cent more than 1.3.

In addition, *kiyi* has a relatively longer head, a narrower body, and, on the average, more pigmentation. The state of development of the sex organs, especially in females, may also be of aid in separating the two forms, as *kiyi* probably spawns in October and *hoyi* in March.

Only the smaller specimens of *artedi* can be confused with *kiyi*, as the latter has not been seen to attain a length of more than 245 millimeters. *Kiyi* has fewer gill rakers on the first branchial arch and longer paired fins. These characters are compared below:

Gill rakers on the first branchial arch:
- *kiyi*, (34) 36–41 (45), with 14 per cent more than 40.
- *artedi*, (41) 46–50 (55).

Pv/P:
- *kiyi*, (1.1) 1.4–1.7 (2.1), with 7 per cent more than 1.8.
- *artedi*, (1.6) 1.8–2.1 (2.5), with 80 per cent more than 1.8.

Av/V:
- *kiyi*, (0.9) 1–1.3 (1.4).
- *artedi*, (1.3) 1.5–1.7 (2), with 93 per cent more than 1.4.

The body shape of *kiyi*, as seen from the side, is more or less ovate, as contrasted with the elliptical form of *artedi;* the body is narrower and less pigmented; the head and maxillary are relatively longer; the lower jaw is usually longer than the upper and the mandible is usually hooked, while in *artedi* it is usually shorter than the upper. *Kiyi* probably spawns about a month earlier than *artedi* (in October), and the state

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[97] All figures given under this section are based on an examination of all collected specimens, except proportions for *artedi*, which are given for specimens less than 225 millimeters in length.

of development of the sex organs is at times, therefore, a systematic character in differentiating certain specimens.

A discussion of the differences between *kiyi* and *johannæ, alpenæ, zenithicus,* and *reighardi* is given on pages 352, 365, 390, and 402.

GEOGRAPHICAL DISTRIBUTION

All my records on the occurrence of the kiyi are assembled in Table 48 and are platted on the chart in Figure 4. They are 22 in number, and all but two (which were made from the trout nets) are from examinations of the commercial chub hauls. They show that the species has been taken out of all the ports visited, and it may be concluded that it is distributed generally throughout the lake where suitable conditions obtain.

BATHYMETRIC DISTRIBUTION

All the records of the vertical distribution of the kiyi are derived from an examination of the 2½ and 2¾ inch chub nets, which are set at varying depths in the lake, and the 4½-inch trout nets, usually set in less than 40 fathoms. The shallowest gang that took *kiyi* was of chub nets set in 20 to 35 fathoms (record 7) and of 4½-inch nets set in 28 to 32 fathoms (record 16), and the deepest in chub nets from 71 to 90 fathoms (record 2). In the lifts from shallow water the species was rare, but it was distributed throughout the extent of the deepest gang. It is certain, then, that the species comes into water as shallow as 30 fathoms and possibly shallower, though it never has been seen from the 1½-inch nets set in 26 to 40 fathoms (see p. 354), and it descends into depths of 90 fathoms and probably deeper.

RELATIVE ABUNDANCE

The data on relative abundance of the kiyi are only approximate. Fish were very rare in the 2½ and 2¾ inch nets in 1920 (see p. 354); and the kiyi, being a small species, is not taken so abundantly in the 2¾-inch nets as in those of smaller mesh, so that the percentages of abundance are lower necessarily for the lifts of the 2¾-inch nets. The data, however, all bear the same aspect and probably indicate what would be the result of more careful investigation.

No *kiyi* occurred in the lifts of the 2⅜ to 2¾ inch nets made in Green Bay on August 16, 1920, off Little Sturgeon and 8 miles south of Green Island in 11 and 16 fathoms, and on August 18, 1920, 4 miles west of Boyer Bluff in 18 to 24 fathoms; in Lake Michigan proper on June 22, 1920, off Cathead Light in 40 to 60 fathoms; on August 10, 1923, 8 miles NNW. of Big Rock Point, Mich., in 45 to 50 fathoms; on March 24, 1919, in an unknown location off Milwaukee, Wis.; on September 24, 1920, 9 miles NNE., and on November 15, 1920, 20 miles ESE. of Milwaukee, Wis., in 50, 22 to 25, and 28 to 35 fathoms, respectively; on November 19, 1920, 10 miles NNW. of Michigan City, Ind., in 18 fathoms, and 17 miles NNW. in 28 to 32 fathoms, and 17½ miles NW. by N. ¾ N. in 32 fathoms; on March 2, 1921, 21 miles NNW. and on March 4, 1921, 15 miles NW. by N. ½ N. in 28 to 30 fathoms. The November lifts were made on or near the spawning grounds of *zenithicus* and the March lifts on the spawning grounds of *hoyi*, so that the absence of *kiyi* is not so surprising;

but it is obvious from the data that follow that the sets were probably in too shallow water. The species was rare in examined lifts made on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms (record 4); on September 3, 1920, 22 miles NW. by N. ½ N. of Michigan City, Ind., in 30 to 40 fathoms (record 9); on October 11, 1920, 20 miles N. by W. ¾ W. in 30 to 40 fathoms (record 10); and on November 8, 1920, 18 miles NNW. in 30 to 38 fathoms (record 11); on July 31, 1923, 5 miles northwest of Cathead Light, Mich., in 40 to 60 fathoms (record 18); on June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55 fathoms, and on August 11, 1923, 3 miles NW. ½ W. in 35 to 60 fathoms (records 19 and 21); on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms (record 22). It made up 35 to 65 per cent of the catches of the nets lifted on September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms[98] (record 6); on October 4, 1920, 9 miles north of Point Betsie, Mich., in 60 to 70 fathoms (record 17); on September 23, 1920, 27 miles ESE. of Milwaukee, Wis., in 60 fathoms (record 8); on August 23, 1920, 12 miles E. by S. of the mouth of the Sturgeon Bay ship channel, Wis., in 60 to 70 fathoms (record 3); and on August 19, 1920, 20 miles E. ½ N. of Rock Island, Wis., in 71 to 90 fathoms (record 2). It occurred in lifts made on March 20, 1919, 12 miles west of Grand Haven, Mich., in 50 to 55 fathoms (record 13); May 26, 1922, 8 miles northeast of Port Washington, Wis., in 20 to 35 fathoms (record 7); June 30, 1920, 3 miles northwest of Charlevoix, Mich., in 40 to 65 fathoms (record 20); August 18, 1920, 14 miles E. ¾ N. of Rock Island, Wis., in 30 to 50 fathoms (record 1); August 30, 1920, 17 miles and 12 miles W. ½ S. of Ludington, Mich., in 60 to 70 and 40 to 50 fathoms (records 14 and 15); and on October 1, 1920, 11 miles southeast of Sheboygan, Wis., in 60 fathoms (record 5), but in what numbers is not known.

In the seven samples of the catches of the 1½-inch bait nets in 28 to 40 fathoms examined at Sheboygan, Port Washington, and Racine, Wis., at Michigan City, Ind., and at Manistee, Northport, and Traverse City, Mich., no kiyis occurred, and only two specimens were ever seen among the bloaters brought in ensnarled in the lifts of the 4½-inch nets. These were taken on August 28, 1920, 9 miles northwest of Manistee, Mich., in 28 to 32 fathoms (record 16), and on November 19, 1920, 30 miles NNW. of Michigan City, Ind., in 48 to 50 fathoms (record 12).

In summary, *kiyi* was not found in 7 samples from 1½-inch nets at 28 to 40 fathoms, or in 10 catches of chub nets from 11 to 50 fathoms or 3 from 40 to 60 fathoms. It was rare in seven catches of the chub nets from 30 to 60 fathoms and in one from 60 to 70 fathoms. It was common only in five chub catches from 60 to 90 fathoms. It occurred once in unknown numbers in a catch of the chub nets as shallow as 20 to 35 fathoms and once in trout nets at 28 to 30 fathoms and 48 to 50 fathoms. It appears from the foregoing that the species attains its maximum density from 60 to 70 fathoms and probably deeper, and that it ranges occasionally as shallow as 30 fathoms or perhaps less. The fishermen at Grand Haven and Frankfort, Mich., state that a small, thin, large-eyed fish, which undoubtedly is *kiyi*, occurs deeper than 70 fathoms, and it is possible that *kiyi* is distributed throughout the vast central basins of the lake.

[98] The field notes show that the species was six times more abundant in the 65-fathom end of the gang.

BREEDING HABITS

No spawning grounds of the species are known positively, but W. B. Chapin, of Frankfort, Mich., states that during October spawning kiyis are taken in the 70-fathom end of the chub nets that are set on the "northwest shoal," about 12 miles to the northwest of Frankfort. Males taken at Sheboygan, Wis., on October 1, 1920, showed incipient pearl organs, but none of the females had eggs even approaching the ripe state. At Frankfort on October 4, 1920, a few females were nearly ripe, and many showed well-developed eggs. Two pearled males were taken at Michigan City, Ind., on October 11, 1920, and a spent female was found there on November 8, 1920, among several females that had not yet spawned. If the fish referred to by Mr. Chapin are kiyis on their spawning grounds, then the fish observed by me at Frankfort were those that had not yet ripened sexually; or there may be a variation of a few weeks in the beginning of the spawning season, as in the case of the coregonids of the basin, which spawn in shallower water.

Leucichthys kiyi kiyi of Lake Huron

The *kiyi* of Lake Huron is like the typical form, except that rarely has it been seen so large. In Lake Michigan individuals of 20 to 23 centimeters in length are common, but specimens of such size have been seen rarely in Lake Huron. The principal systematic characters capable of numerical expression are compared below.

Gill rakers on the first branchial arch:
- Michigan, (34) 36–41 (45).[99]
- Huron, (34) 36–40 (44).[1]

Lateral-line scales:
- Michigan, (71) 77–87 (91).
- Huron, (70) 75–83 (89).

L/H:
- Michigan, (3.7) 3.8–4.1 (4.3).
- Huron, (3.5) 3.6–3.9 (4.1).

H/E:
- Michigan, (3.6) 3.8–4.2 (4.3).
- Huron, (3.3) 3.6–3.8 (4.3).

Pv/P:
- Michigan, (1.1) 1.4–1.7 (2.1).
- Huron, (1.1) 1.4–1.7 (1.9).

Av/V:
- Michigan, (0.96) 1–1.3 (1.4).
- Huron, (0.93) 1–1.2 (1.4).

It appears that the scales on the average are less numerous in the lateral line in Huron individuals. The chief difference between the specimens from the two lakes, however, is in the head and eye proportions, but as the Huron specimens are much smaller, on the average, the differences are such as are to be expected and it is likely that in specimens of comparable size they would not exist. (It may be seen in the section on variations that L/H and H/E figures for the few large specimens are very close to the ranges given for these values for the Lake Michigan race, most of which are more than 200 millimeters long.)

The color in life is not different from that of the Michigan form. Alcoholics show about the same degree of pigmentation, and its distribution also is approximately the same.

No pearled fish have been seen, but at least the males probably develop pearl organs in the breeding season.

VARIATIONS

Virtually all the specimens collected have come from the central basin of the lake, and there is no material for studies of local variation. There are only 16 indi-

[99] These figures are based on an examination of 174 specimens, which range in length from 122 to 245 millimeters.

[1] Figures for Lake Huron are based on an examination of 226 specimens, which range in length from 105 to 249 millimeters.

viduals in my collection longer than 200 millimeters, and these have, on the average, a proportionally smaller head and eye than the rest. L/H for these specimens is 3.8–4, as compared with (3.5) 3.6–3.8 (4.1) for the rest; and H/E is (3.7) 3.9–4 (4.3), as compared with (3.3) 3.6–3.8 (4) for the others. See also Table 51, where are compared in detail five specimens longer than 200 millimeters and five smaller.

COMPARISONS [2]

Kiyi usually can be confused only with the juveniles of other Leucichthys, except *hoyi,* as kiyis of greater length than 20 centimeters are rarely found. For the distinguishing characters between *kiyi* and *johannæ,* see page 358; between *kiyi* and *alpenæ,* see page 371; between *kiyi* and *zenithicus,* see page 396; and between *kiyi* and *nigripinnis,* see page 423.

From *hoyi, kiyi* is distinguished by its more ovate body shape and more acutely triangular head, as seen from the side; by its fewer gill rakers on the first branchial arch, more lateral-line scales, and longer paired fins. The characters that can be expressed numerically are compared for the two species below:

Gill rakers on the first branchial arch:
- *kiyi,* (34) 36–40 (44), with 12 per cent more than 40.
- *hoyi,* (37) 40–43 (47), with 71 per cent more than 40.

Lateral-line scales:
- *kiyi,* (70) 75–83 (89), with 71 per cent more than 76.
- *hoyi,* (63) 68–76 (84), with 12 per cent more than 76.

Pv/P:
- *kiyi,* (1.1) 1.4–1.7 (1.9), with 15 per cent more than 1.6.
- *hoyi,* (1.4) 1.7–1.9 (2.2), with 85 per cent more than 1.6.

Av/V:
- *kiyi,* (0.9) 1–1.2 (1.4), with 34 per cent more than 1.1.
- *hoyi,* (1) 1.2–1.4 (1.7), with 90 per cent more than 1.1.

Kiyi can be confused only with small *artedi,* as it does not grow large and usually can be distinguished from these at once by the shape of the body, which in *kiyi* is more ovate in outline, as seen from the side; by the many fewer gill rakers on the first branchial arch, much longer paired fins, and larger head and eye. The two species are compared below in those characters that can be expressed numerically:

Gill rakers on the first branchial arch:
- *kiyi,* (34) 36–40 (44), with 12 per cent more than 40.
- *artedi,* (40) 45–50 (53), with 99 per cent more than 40.

L/H:
- *kiyi,* (3.5) 3.6–3.9 (4.1).
- *artedi,* (4) 4.2–4.5 (4.8), with 89 per cent more than 4.1.

H/E:
- *kiyi,* (3.3) 3.6–3.8 (4.3), with 21 per cent more than 3.8.
- *artedi,* (3.6) 3.8–4 (4.4), with 66 per cent more than 3.8.

Pv/P:
- *kiyi,* (1.1) 1.4–1.7 (1.9).
- *artedi,* (1.7) 1.9–2.1 (2.3), with 68 per cent more than 1.9.

Av/V:
- *kiyi,* (0.9) 1–1.2 (1.4).
- *artedi,* (1.3) 1.6–1.7 (1.9), with 97 per cent more than 1.4.

[2] Figures in this section are given for all specimens collected except for the proportions of *artedi.* These involve only those specimens less than 225 millimeters in length.

Kiyi has also a narrower body and a much longer maxillary, snout, and mandible. The latter is usually equal to or shorter than the upper jaw in *artedi* and longer and hooked in *kiyi*. *Artedi* is also more pigmented, especially on the dorsal surface.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of the kiyi in Lake Huron are given in Table 50 and are platted in Figure 5. There are 20 records made during three years and show the species to occur in Georgian Bay and in the central basin of the main lake. At each end of the lake the water becomes shallower, and probably conditions are less suitable there.

BATHYMETRIC DISTRIBUTION

The sources of the data on depth distribution of *kiyi* are, for the most part, the 2¾-inch chub nets that are set at depths of 60 fathoms or more. A few specimens were taken in a special set of 1½-inch net made on September 13, 1919, off Presque Isle Light in 60 fathoms (record 11). Chub nets took specimens in 1917 on September 7, 12, and 21 and on October 17 and 20, and on September 18, 1919, in the center of the lake east of the Alpena can buoy in 65 to 80 fathoms (records 1, 2, 8, 9, 10, and probably 13); on September 14 and 19, 1917, in the center of the lake northeast of the can buoy in 65 to 80 fathoms (records 3 and 5); on September 18, 1917, 17½ miles N. by E., on September 20, 1917, 14 miles NE. by E., on September 21, 1917, 17 miles NE. by N. ¾ N., on September 18, 1919, 14 miles N. by E., on June 30, 1923, 17 miles NE. by N. ¾ N., on July 5, 1923, 18 miles NE. ¾ E., and on July 7, 1923, 13 miles NE. ½ N. of Thunder Bay Island in 60 to 100 fathoms (records 4, 6, 7, 12, 14, 16, and 17); and on July 2, 1923, 20 miles E. by N. of the can buoy in 60 to 70 fathoms (record 15). In Georgian Bay specimens were taken on July 30, 1919, 21 miles east of Surprise Shoal and off Wiarton in about 60 fathoms, and on October 6, 1919, off White Bluff in 70 fathoms (records 18, 19, and 20). A comparison with Tables 18 and 58, which give distribution data for *johannæ* and *hoyi*, shows that not all lifts of the chub nets took *kiyi*. Three lifts off Cheboygan, Mich., at the north end of the lake, and one off Harbor Beach, Mich., at the south end of the lake, in 35 to 50 fathoms, took no *kiyi;* nor were *kiyi* always present in the lifts of the chub nets made off Alpena in more than 60 fathoms. No *kiyi* ever were seen among the small fish taken in the 1½-inch bait nets off Cheboygan (one lift), Alpena (two lifts), and Harbor Beach (two lifts); nor were any included among the small fish taken on eight occasions by the 4½-inch trout and whitefish nets off Alpena set in 30 fathoms or less. (See Table 58.) It appears likely, therefore, that *kiyi* prefers only the deeper waters and occurs, during most of the season at least, only at depths of more than 60 fathoms.

RELATIVE ABUNDANCE

The kiyi has absolutely no commercial significance in Lake Huron, and therefore its relative abundance, as compared with that of the chubs, is of no interest. Inasmuch as virtually all the specimens collected have been found accidentally ensnarled in nets of a mesh too large to gill them, their number in these nets is no satisfactory index of their abundance; there are no data on the absolute abundance of the species, except that a 1½-inch net about 350 feet long, lifted from 60 fathoms

off Presque Isle Light on September 13, 1919 (record 11), took only 8 kiyis among some hundred other fish.

BREEDING HABITS

Nothing is known of the breeding habits of *kiyi.* Female specimens collected as late as October 17 and 20, 1917, showed eggs approaching maturity, and probably the species spawns during October or November. October is said to be the time of spawning in Lake Michigan.

FOOD

The contents of 20 stomachs of specimens taken off Alpena, Mich., on September 19, 1919, in more than 60 fathoms consisted almost exclusively of Mysis. One specimen had swallowed a Pisidium, one a developing Leucichthys egg, and three had picked up fragments of wood.

Leucichthys kiyi kiyi of Lake Superior

The *kiyi* of Lake Superior resembles the typical form in shape and appearance, but apparently it does not grow so large, as the largest individual seen measured only 204 millimeters, compared with a recorded maximum of 245 millimeters for the Lake Michigan form. The chief systematic characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (34) 36–41 (45).[3]
- Superior, (36) 37–41 (45).[4]

Lateral-line scales:
- Michigan, (71) 77–87 (91).
- Superior, (72) 76–84 (87).

L/H:
- Michigan, (3.7) 3.8–4.1 (4.3).
- Superior, (3.5) 3.7–3.9 (4.1).

H/E:
- Michigan, (3.6) 3.8–4.2 (4.3).
- Superior, (3.4) 3.5–3.8 (4.1).

Pv/P:
- Michigan, (1.1) 1.4–1.7 (2.1).
- Superior, (1.1) 1.3–1.5 (1.7).

Av/V:
- Michigan, (0.9) 1–1.3 (1.4).
- Superior, (0.9) 1–1.2 (1.4).

It appears that the Superior kiyi has somewhat fewer scales in the lateral line and an average larger head and eye and longer pectoral fins. As the Superior specimens are much smaller than those that have been examined from Michigan, the differences in proportions involving the head and eye are such as might be expected and a comparison of these characters is not conclusive. In addition, the Superior form has, on the average, a longer anal base but with only slightly if any more anal rays, and in relation to the head a shorter snout, longer jaw, and longer gill rakers. Except for the head-snout proportions, which for Superior specimens is (3.3) 3.5–3.7 (4.1)[5] and for Michigan specimens (3.2) 3.4–3.6 (3.9), and for anal rays, which for Superior specimens are (10) 11–12 (14)[6] and for Michigan specimens (9) 10–12 (16),[7] the other characters are, for the most part, so variable that they are not given in fuller detail than is shown in the analysis of 10 specimens from each lake in Tables 49 and 53.

[3] These and unmarked figures for Lake Michigan are based on an examination of 174 specimens that range in length from 122 to 245 millimeters.

[4] These and unmarked figures for Lake Superior are based on an examination of 81 specimens ranging in length from 132 to 204 millimeters.

[5] Sixty-six specimens.

[6] Sixty-two specimens.

[7] One hundred and forty-four specimens.

The color of no live fish has been recorded, but probably it does not differ from that of Michigan specimens. Alcoholics do not differ materially in details of pigmentation, except that the anal and the ventrals more often show pigment.

At least the males develop pearl organs in the breeding season. Specimens obtained in November and December, 1922, had traces of nuptial excrescences, but most of them had been lost by friction before the specimens were received. The development of the pearls probably is like that of other members of the genus.

VARIATIONS

Virtually all the specimens collected have been taken off Marquette, Mich., and nearly all are equal in size, so that there are no data on age or racial variations.

The smallest collected individual, 132 millimeters long, was found sexually mature.

COMPARISONS [8]

The kiyi closely resembles *hoyi* and at all times may be confused with it. All other species in Lake Superior attain greater size than *kiyi*, and therefore it can be confounded only with juveniles of these species.

Kiyi has fewer gill rakers on the first branchial arch, more scales in the lateral line, longer paired fins, and the base of the anal fin is relatively longer than in *hoyi*. The body shape, as seen from the side, is less elliptical in *kiyi* on account of the more sudden rise of the predorsal contour. The characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- *kiyi*, (36) 37–41 (45), with 24 per cent more than 40.
- *hoyi*, (37) 41–44 (49), with 83 per cent more than 40.

Lateral-line scales:
- *kiyi*, (72) 76–84 (87), with 88 per cent more than 75.
- *hoyi*, (65) 69–78 (84), with 29 per cent more than 75.

Pv/P:
- *kiyi*, (1.1) 1.3–1.5 (1.7), with 10 per cent more than 1.5.
- *hoyi*, (1.4) 1.5–1.8 (2), with 76 per cent more than 1.5.

Av/V:
- *kiyi*, (0.9) 1–1.2 (1.4), with 7 per cent more than 1.2.
- *hoyi*, (0.9) 1.1–1.3 (1.6), with 36 per cent more than 1.2.

L/AB:
- *kiyi*, (7) 8–9 (10), with 8 per cent more than 9.
- *hoyi*, (7.5) 9–10 (11.5), with 58 per cent more than 9.

The dorsal contour of the head in *kiyi* is more or less convex and the premaxillaries more vertical than in *hoyi*, in which there is almost a straight line from the tip of the premaxillaries to the occiput. The effect of these lines on the outline of the head, as seen from the side, makes the head of *kiyi* more elongated and obtuse triangular, while that of *hoyi* is rather broad and acute triangular with the mouth at a higher level. The anal fin is more often pigmented in *kiyi*. The body of *kiyi* is somewhat darker, as a rule.

For differences between *kiyi* and *zenithicus*, see page 381, between *kiyi* and *reighardi*, page 411, and between *kiyi* and *nigripinnis*, seepage 427.

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[8] Figures are given in this section for all collected specimens of each species except for proportions of *artedi*, which are given or those specimens less than 225 millimeters in length.

Kiyi can be confused only with small *artedi,* as the former is not known to grow large. The body shape of *kiyi* is ovate, as seen from the side, as compared with the elongate elliptical form of *artedi;* the gill rakers on the first branchial arch are fewer, and the paired fins, maxillary, head, and eye are relatively longer, as will appear from the figures given:

Gill rakers on the first branchial arch:
- *kiyi,* (36) 37–41 (45), with 24 per cent more than 40.
- *artedi,* (41) 45–48 (53).

L/H:
- *kiyi,* (3.5) 3.7–3.9 (4.1).
- *artedi,* (4) 4.2–4.6 (4.8), with 92 per cent more than 4.1.

H/E:
- *kiyi,* (3.4) 3.5–3.8 (4.1), with 3 per cent more than 3.9.
- *artedi,* (3.4) 4–4.2 (4.5), with 77 per cent more than 3.9.

H/M:
- *kiyi,* (2.2) 2.4–2.5 (2.6).
- *artedi,* (2.5) 2.7–3 (3.2), with 88 per cent more than 2.6.

Pv/P:
- *kiyi,* (1.1) 1.3–1.5 (1.7).
- *artedi,* (1.6) 1.9–2.2 (2.3), with 90 per cent more than 1.7.

Av/V:
- *kiyi,* (0.9) 1–1.2 (1.4).
- *artedi,* (1.4) 1.5–1.8 (1.9), with 95 per cent more than 1.4.

In addition, *kiyi* has, on the average, fewer lateral-line scales, a longer snout, and a longer mandible. Few specimens of *artedi* have been found sexually mature under 200 millimeters, while *kiyi* commonly is mature at 140 millimeters.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of the *kiyi* in Lake Superior (11 records) are assembled in Table 52 and are platted in Figure 3. By comparison with a similar table for *hoyi* (Table 60), it appears that *kiyi* is distributed by no means so generally as the former; and from all the data at hand it can be stated with certainty only that the species occurs in the deeper waters of the southern half of the lake. Its absence in the inspected catches from apparently suitable depths in the northern sector must not be taken to indicate its absence in this area, however, especially when its rarity in the south, except during the breeding season, is taken into consideration; and further investigation probably will discover the species throughout the lake where conditions are suitable.

BATHYMETRIC DISTRIBUTION

Kiyi is preeminently a deep-water form in Lake Superior, as in all the other lakes in which it is known to occur. Of the 11 lifts that have yielded specimens, 4 were made at unknown depths, but probably from at least 40 fathoms. Only one of the rest was made as shallow as 40 to 50 fathoms (record 11). The remaining specimens collected were taken from sets that, if they ranged as shallow as 40 or 50 fathoms, extended also to greater depths (records 3, 9, and 10). Except during the spawning season (records 5 and 6), the majority of specimens collected came from a gang of nets set in 100 fathoms (record 2). It is interesting to note by comparison with Table 60, which shows the data on the occurrence of *hoyi,* that *kiyi*

does not necessarily occur everywhere at depths of more than 40 or even 60 fathoms, but for the present we may say that during the year the species ranges between the depths of 40 and 100 fathoms. As no *kiyi* occurred in the shallow-water sets that took *hoyi,* the inshore limit of their range, at least when not spawning, probably may be set around 40 fathoms. There are no data to fix the maximum depths which the species frequents.

RELATIVE ABUNDANCE

As, on account of its small size, *kiyi* has no commercial importance, it is not fished for, and its abundance can only be determined relative to that of *hoyi,* which is like it in respect to size and usefulness. Except possibly in the lifts made in late November and early December, 1922 (records 5 and 6), when the species was spawning, *kiyi* never has been anything but rare in the inspected catches; and except for the records made off Marquette, Mich., Apostle Islands, Wis., and Coppermine Point, Ontario (records 3, 9, 10, and 11), all of them from nets extending into 40 fathoms, it never has been taken in company with *hoyi.* On these four occasions only stray specimens were found entangled with the latter.

BREEDING HABITS

Specimens collected as late as October 3, 1917, off Grand Marais, Mich., were not yet ripe, although females taken on this date showed eggs approaching the ripe state. Of 13 specimens received from off Marquette, Mich., on November 22, 1922, 9 were males from which milt could be forced and the 4 females had eggs nearly ripe. Of the 39 fish received from the same source on December 5, 1922, only 6 were males, and of the 33 females the majority were spawning or spent. These data indicate that the spawning season falls in late November or early December.

Unfortunately there have been no exact localities recorded for these spawning fish taken off Marquette, but Prof. J. N. Lowe, of the Northern Normal School, who sent the specimens, states that they were taken off Granite Island, probably in 70 fathoms. This information then fixes at least one spawning ground for the species in the lake, and doubtless there are others.

Leucichthys kiyi orientalis (new subspecies) of Lake Ontario

The *kiyi* of Lake Ontario attains about the same maximum size as the typical form, except that in virgin waters extreme examples measured 250 millimeters and a single specimen of 263 millimeters was seen. The general appearance of the two forms is the same, but the Ontario representative differs rather markedly in several characters. Values for certain of these are compared below:

Gill rakers on the first branchial arch:
- Michigan, (34) 36–41 (45).[9]
- Ontario, (41) 43–46 (48).[10]

Lateral-line scales:
- Michigan, (71) 77–87 (91).
- Ontario, (71) 76–87 (91).

L/H:
- Michigan, (3.7) 3.8–4.1 (4.3).
- Ontario, (3.8) 4.1–4.2 (4.4).

H/E:
- Michigan, (3.6) 3.8–4.2 (4.3).
- Ontario, (3.6) 3.9–4.2 (4.4).

Pv/P:
- Michigan, (1.1) 1.4–1.7 (2.1).
- Ontario, (1.5) 1.7–2 (2.2).

Av/V:
- Michigan, (0.9) 1–1.3 (1.4).
- Ontario, (1) 1.2–1.4 (1.6).

[9] These and succeeding figures are based on an examination of 174 specimens ranging in length from 122 to 245 millimeters.

[10] These and succeeding figures for Lake Ontario are based on an examination of 135 specimens ranging in length from 148 to 263 millimeters.

The specimens from the two lakes are of approximately the same average size, and the figures given are comparable, therefore. It appears that the Ontario form has many more gill rakers, much shorter paired fins, and a somewhat shorter head. Other characters, as number of scale rows around the body, number of fin rays, and mandible length, are approximately as in the typical form. The Ontario representative tends to have, on the average, longer gill rakers, a shorter dorsal, a broader caudal, and blunter head, but these characters are so variable within each race that no further account of their variability is given than is found in the detailed comparison of 10 specimens from each lake in Tables 49 and 55.

The form appears sufficiently well marked to merit a name, and I propose to call it *orientalis*. Specimen No. 54064 of Table 55, taken on July 19, 1921, off Wilson, N. Y., in 65 fathoms is designated as the type. It is catalogued as No. 88352 in the United States National Museum.

The color in life is not different from that of the typical form. Alcoholics show, on the average, more pigment on the head and body and on the abdominal fins, especially on the ventrals and the anal.

At least the males of the species develop pearl organs in the breeding season. Specimens collected in the latter part of July, 1921, off Wilson, N. Y., had traces of pearls, and specimens taken in early September off Oswego, N. Y., showed well-developed pearls. For the most part these have been lost by friction in the preserved specimens, so that no detailed description is possible, but in general they are distributed over the head and body and have the same general shape, size, and location on the scale as in other members of the genus whose breeding dress has been described.

VARIATIONS

Racial variations.—No differences are observable between the groups of specimens collected from the various parts of the lake, but it is not improbable that, if sufficient numbers were gathered together, local races might be differentiated.

Size variations.—Most of the collected specimens have been gilled in 2½-inch nets and are therefore longer than 200 millimeters, so that there are no groups of specimens of different sizes available to determine how the body parts change in size with growth.

Four specimens as small as 148 to 177 millimeters long have been seen, and all had maturing gonads.

COMPARISONS [11]

Kiyi can be confused only with *hoyi* or possibly *nigripinnis prognathus*. *Kiyi* and *hoyi* attain about the same maximum size and resemble one another rather closely. The shape of the body, as seen from the side, is decidedly less elliptical in *kiyi*, as the predorsal contour rises rather abruptly from the occiput and the head is rather more elongated. Absolute differences in characters that can be expressed numerically are wanting, but there are several characters that show average differences, and by the use of these most specimens can be identified properly.

[11] Figures in this section are given for all specimens collected except those of proportions for *artedi*, which are based on specimens 225 millimeters and more in length.

Lateral-line scales:
kiyi, (71) 76–87 (91), with 89 per cent more than 76.
hoyi, (63) 68–76 (81), with 8 per cent more than 76.

H/E:
kiyi, (3.6) 3.9–4.2 (4.4), with 7 per cent more than 4.2.
hoyi, (3.7) 4–4.5 (4.7), with 39 per cent more than 3.7.

H/ad:
kiyi, (2.7) 3.2–3.7 (4.1), with 15 per cent more than 3.7.
hoyi, (3.2) 3.6–4.3 (5), with 72 per cent more than 3.7.

Scale rows in front of dorsal and ventrals:
kiyi, (40) 41–44 (47), with 79 per cent more than 41.
hoyi, (37) 40–41 (46), with 25 per cent more than 41.

The ventrals are also somewhat longer, relative to the distance from their insertion to that of the anal (Av/V), in *kiyi*. As *kiyi* spawns in August and *hoyi* in November or later, the state of development of the sex organs will often be serviceable also in separating individuals of the two species.

As only one specimen of *prognathus* is known to exist in collections, it is not possible to give criteria for distinguishing the two forms, but there are decided differences between the two in respect to absolute size attained and the time of spawning. The largest collected *kiyi* measures only 263 millimeters, and nets of 2½-inch mesh are required for the capture of the species, while *prognathus* was commonly larger than 300 millimeters and was taken only in nets of 3-inch or larger mesh. The species differed, also, in time of spawning. *Kiyi* spawns in August, while *prognathus* is said to have spawned in January.

Usually *kiyi* can be distinguished at once from *artedi* by the more ovate body outline, as seen from the side, as in the former the predorsal contour is strongly arched. In addition, *kiyi* has fewer gill rakers on the first branchial arch, a larger head and eye, a longer mandible, and paired fins. These characters are compared below for the two species:

Gill rakers on the first branchial arch:
kiyi, (41) 43–46 (48), with 15 per cent more than 46.
artedi, (41) 46–50 (54), with 67 per cent more than 46.

L/H:
kiyi, (3.8) 4.1–4.2 (4.4), with 5 per cent more than 4.3.
artedi, (3.7) 4.3–4.7 (4.9), with 74 per cent more than 4.3.

H/E:
kiyi, (3.6) 3.9–4.2 (4.4), with 7 per cent more than 4.2.
artedi, (3.9) 4.1–4.4 (4.9), with 56 per cent more than 4.2.

Pv/P:
kiyi, (1.5) 1.7–2 (2.2), with 11 per cent more than 2.
artedi, (1.7) 1.9–2.1 (2.5), with 38 per cent more than 2.

Av/V:
kiyi, (1) 1.2–1.4 (1.6), with 7 per cent more than 1.4.
artedi, (1.3) 1.5–1.8 (2), with 94 per cent more than 1.4.

Mandible compared with upper jaw:
kiyi, shorter, 2 equal, 30 longer, 98 or 75 per cent longer.
artedi, shorter, 130 equal 121 longer, 77 or 23 per cent longer.

Kiyi spawns in August and *artedi* spawns in late November, so that the state of development of the sex organs, particularly of females, also is a valuable character for separating the two species.

A discussion of the distinctions between *kiyi* and *reighardi* is given on page 414.

GEOGRAPHICAL DISTRIBUTION

The records on the occurrence of *kiyi* in Lake Ontario are given in Table 54 and are shown platted on the lake chart in Figure 7. For the most part they are derived from the use of the special 2½ and 2¾ inch nets. It appears that *kiyi* was taken out of every port from which the nets were set, and as the ports are distributed along the shore line of the lake it may be concluded safely that *kiyi* occurs throughout the waters of the lake where suitable conditions obtain.

BATHYMETRIC DISTRIBUTION

The chief data on the depth distribution of the kiyi are derived from the use of the 2½ and 2¾ inch nets, which were set under my direction during the summers of 1921 and 1923. A few specimens have been seen, also, that were taken accidentally in the nets of larger mesh. All nets were set between the depths of 20 and 75 fathoms and in every locality took specimens of the species. No effort was made to determine the limits of the range of the species, so that for the present it can be stated only that individuals of the species range during the year between 20 and 75 fathoms.

RELATIVE ABUNDANCE

The experimental nets did not take *kiyi* abundantly at any time, but it is interesting to record the relative abundance of this and the other species taken with it. On July 19, 1921, 6½ miles N. by W. ½ W. of Wilson, N. Y., in 65 fathoms (record 12), 75 per cent of the catch was of *kiyi*. On June 25, 1921, 5 miles north, in 50 fathoms (record 10), *kiyi* comprised 40 per cent of the fish taken; on July 4, 1921, 7 miles off Braddock Point Light, in 65 fathoms (record 8), the percentage was about one-third, and on July 12, 1921, 8½ miles NNW. of Sodus Point, N. Y, in 60 fathoms (record 7), about one-fourth. But few *kiyi* were taken in other lifts made 20 miles S. by W. of Presque Isle Light, Ontario, on June 10, 1921, in 40 to 50 fathoms (record 2); on June 29, 1921, 13 miles E. ½ S. of Bronte, Ontario, in 40 to 50 fathoms (record 1); on June 23, 1921, 3 miles north of Wilson, N. Y., in 30 fathoms (record 9), on July 16, 1921, 5 miles north, in 50 fathoms (record 11), and on July 21, 1921, 2 miles north, in 20 fathoms (record 13); on August 30, 1923, 14 miles west of Sandy Pond, N. Y., in 60 fathoms (record 3); and on September 4, 1923, 8½ miles W. by N. ½ N. of Oswego, N. Y., in 70 to 75 fathoms (record 6). The specimens taken in the 3-inch nets off Selkirk and Oswego, N. Y. (records 4 and 5), were accidental captures.

It must be borne in mind that, unlike Lakes Michigan and Huron, in which grounds suitable for deep-water Leucichthys or chubs have been located through seasons of experience, most of Lake Ontario never has been exploited for these species, and the areas where they occur most abundantly are as yet unknown. For this reason the experimental nets, from the use of which these data on relative abundance are derived, were of necessity set at random in the lake, with depth alone as the directing factor, and therefore it can not be expected that the nets will yield conclusive data on absolute abundance or even on relative abundance. In the case of the kiyi, from our knowledge of the habits of the species in other lakes such observations as have been recorded may be taken to indicate that the center of abundance of *kiyi* is attained in depths of 60 fathoms or more.

BREEDING HABITS

No spawning *kiyi* have been taken. Males collected on July 19 and 21, 1921, off Wilson, N. Y., were pearled, and females showed well-developed ova, although none were by any means ripe. Males and females taken on September 4, 1923, off Oswego, N. Y., were spent, but the males still showed pearl organs. Females from the University of Toronto collection taken off Port Credit, Ontario, on March 28, 1926, showed ovaries that had not been spent recently. It is apparent, then, that the spawning season for the species must fall in August or thereabouts. At what depths or on what bottom the eggs are laid is not known.

LEUCICHTHYS HOYI Gill

The Bloater (Fig. 23)

Argyrosomus hoyi Gill, in Hoy, 1872, p. 99, Lake Michigan off Racine; Milner, 1874, pp. 86–87, in part, Lake Superior; not of Evermann and Smith, 1896; not of Jordan and Evermann, 1911.

Argyrosomus prognathus Evermann and Smith, 1896, pp. 314–317, in part, Lakes Huron and Michigan.

Leucichthys johannæ Jordan and Evermann, 1911, pp. 24–26, in part, Lakes Huron and Michigan; not Pls. III or V.

Leucichthys hoyi has been described from Lake Michigan but occurs also in Lakes Nipigon, Superior, Huron, and Ontario. In all five bodies of water it is characterized by its relatively small size, which is seldom over a maximum of 200 millimeters except in two of the lakes (Michigan and Ontario), where it grows regularly large enough to be of commercial importance; its terete body form, as seen from the side, and relatively few lateral-line scales. The Nipigon race differs chiefly in having, on the average, a higher number of gill rakers on the first branchial arch and of scales in the lateral line, and a proportionally longer head, eye, maxillary, and paired fins. The Superior form has a proportionally larger head and eye and longer paired fins and maxillary. The Huron form differs but little in its systematic characters. In Lake Ontario the species seems to be different chiefly in having, on the average, more gill rakers, a proportionally smaller eye, and possibly a somewhat longer head and pectorals. All forms, so far as has been ascertained, prefer relatively shallow water, namely, depths of about 30 fathoms except in Lake Ontario, where they have been found most commonly between 50 and 60 fathoms. The breeding habits are but imperfectly or not at all known, but in Lakes Michigan and Huron the species spawns in late February and early March, and in the other lakes it is known that it does not spawn before December.

Type

A specimen about 137 millimeters long has been selected from two mutilated specimens in the United States National Museum, both bearing the type No. 8902, collected in Lake Michigan off Racine, Wis., probably in March, 1872, by Dr. P. R. Hoy. The reasons for making this selection are given on page 312.

Leucichthys hoyi of Lake Michigan

The bloater is probably the commonest Leucichthys in Lake Michigan. It is one of the smallest members of the genus in the Great Lakes Basin, but in Lake Michigan it is taken abundantly in the 2½-inch chub nets and also in some numbers

in those of 2¾-inch mesh. The largest example seen measures 265 millimeters. The shape of the body, as seen from the side, is elliptical even in the largest or in the deepest individuals; that is, the dorsal contour rises in a smooth curve from the occiput to the insertion of the dorsal fin and slopes gently into the caudal peduncle. The opposite ventral profiles correspond approximately, except that specimens from deep water, particularly the smaller ones, are usually extremely bloated and, unless the gas in the air bladder is released at once, the body remains distorted. Larger individuals have thicker belly walls and do not bloat so conspicuously. The body is usually only moderately deep; the depth most often is contained 3.8 to 4.2 times in the total length. The body is moderately compressed, but with growth the width increases, and the largest specimens are often as subterete in body form as *artedi*. The head is moderate, rather broadly triangular viewed from the side, and is contained (3.6) 4–4.2 (4.6)[12] times in the total length. Its dorsal profile is straight or but faintly convex. The premaxillaries are directed forward and downward and usually make an angle of about 40° with the horizontal axis of the head. Their position is influenced by the frail mandible, which is more or less conspicuously pigmented, provided with a more or less conspicuous symphysial knob, and which in most specimens projects beyond the upper jaw, in that case forcing the premaxillaries to assume a more horizontal position. The mandible in less than one-third of the specimens in the collection is only equal to the upper jaw, but only very rarely is it shorter. The maxillary is moderately long, is contained (2.3) 2.5–2.6 (2.8)[13] times in the head length, and it always shows at least some pigment. The snout, viewed from the side, is pointed. It is usually a trifle shorter than the large eye, which is contained (3.3) 3.7–4 (4.5) times in the head length. The gill rakers on the first branchial arch number (13) 15–16 (18) + (23) 26–28 (31) = (37) 41–44 (48). There are (60) 67–77 (84) scales in the lateral line; only 2 per cent of all specimens examined have 80 or more. Scale rows around the body just in front of the dorsal and ventrals number (38) 40–42 (44),[14] just in front of the adipose and anus (31) 32–34 (35),[14] and around the caudal peduncle at its commencement (22) 23–25 (26).[14] The dorsal rays number (7) 9–10,[15] anal rays (10) 11 (13),[15] ventral rays (10) 11 (12),[15] pectoral rays (14) 15–16 (17),[15] and the branchiostegal rays 8 to 9.[15]

The paired fins are rather long. The pectorals are contained (1.3) 1.7–2 (2.5) times in the distance from their origin to that of the ventrals, and the ventrals are contained (1) 1.2–1.4 (1.7) times in the distance from their origin to that of the anal. The dorsal margin of the pectorals is usually nearly straight.

The color in life is not essentially different from that as described for *johannæ*. In alcohol all color eventually fades and leaves obvious details of pigmentation. The entire dorsal surface is strewn thickly with very fine pigment dots, which, however, do not lend a conspicuous darkened effect except in the prenarial area, where they are concentrated usually. There is sometimes a narrow dark streak down the back, due possibly to differential preservation of the flesh but certainly not to pigment. The pigmentation diminishes on the sides and often is absent below the lateral line but

[12] These and succeeding figures, unless otherwise designated, are based on an examination of 1,161 individuals ranging in length from 82 to 265 millimeters.

[13] One hundred and eight specimens.

[14] Twenty-five specimens.

[15] Thirty specimens.

usually is present on the cheeks, particularly on the oculars. The tip of the mandible is pigmented but seldom is conspicuously dark. The preorbital region is like the cranium in respect to pigmentation, and the maxillary always shows more or less of pigment. All the fins are pale, but the caudal and dorsal are darkest. These show a more or less faint dusky hue on their distal margins. The pectorals often show faint pigment on their longest rays; the anals sometimes have a few dots on the membranes between the rays, but the ventrals, except in very rare cases, are immaculate.

During the breeding season pearl organs are developed by males and by at least some females. Their development apparently is not very different from that described for *johannæ*. However, there are occasionally one or two much smaller pearls flanking the central one of the scales of the scale rows of the sides, and on the scales of the rows dorsad and ventrad to the fourth above and the sixth below there are regularly two or three or even more pearls on each scale, the disparity in size decreasing as the back and belly are approached and the distribution and shape becoming more irregular.

VARIATIONS

Racial variations.—It will be seen from Table 56 that a considerable number of specimens has been collected from almost every port visited. The lowest number from any locality is 8 from Platte Bay, and from all but 5 of the 16 other stations from which specimens were preserved 34 or more specimens have been examined. These collections are fairly uniform in respect to size of individuals, with the exception of the Michigan City and Northport lots, which have a greater proportion of large specimens. Compared in all their important systematic characters, as number of gill rakers on the first branchial arch and of scales in the lateral line, and the relative size of head, eye, and paired fins, there are no differences discernible between the various groups except such slight ones as might be due to inequality in size of the various individuals composing the groups, namely, changes in proportion that are the result of growth.

There is another possibility of racial differentiation, namely, according to habitat. In Lake Huron, for example, it has been observed that specimens from the deepest water differ in certain characters from their shore relatives (see p. 458), but in Lake Michigan it has not been possible, from the collection I have accumulated, to establish any such differences. My specimens, however, do not lend themselves to any such comparisons, as they were collected over a period of several of the warmest months, and it is known that the bloaters move nearer shore at certain seasons, so that a given habitat in the same locality might be occupied by different races during a season. A study of environmental races, then, must be undertaken first in a definite and restricted area over a period of time. For the present all that can be said about variation is that the collection of about 1,000 individuals from 17 stations scattered along the lake's shore does not disclose any striking variation tendencies.

Size variations.—By far the greater number of specimens collected are less than 200 millimeters in length, and the largest ones are but little over that limit. In Table 57 five specimens over 200 and five under 200 millimeters in length are compared extensively, and in Tables 8 to 11 all the specimens over 200 millimeters in

length are compared in certain characters with those smaller. The size differences being slight, no marked contrast is to be expected in the figures for the two classes, but it does appear from the tables that the larger specimens have a somewhat smaller head and eye and shorter paired fins.

Individuals usually have been found to be maturing sexually at 140 millimeters. One specimen of 114 millimeters in length apparently was approaching sexual maturity.

COMPARISONS [16]

Hoyi most nearly resembles *kiyi*. A discussion of the differences between the two forms is given on page 436. The differences between *hoyi* and *johannæ, alpenæ, zenithicus, reighardi,* and *nigripinnis* are given on pages 352, 366, 390, 403, and 419.

Hoyi is distinguishable from *artedi* chiefly by the lower number of gill rakers on the first branchial arch and of scales in the lateral line, by the larger head, longer maxillary and ventral fins, and the length of the lower jaw, which in *hoyi* is practically in all cases equal or longer than the upper but in *artedi* is equal or more often shorter. Those characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- *hoyi,* (37) 41–44 (48), with 5 per cent more than 45.
- *artedi,* (41) 46–50 (55), with 86 per cent more than 45.

Lateral-line scales:
- *hoyi,* (60) 67–77 (84), with 7 per cent more than 77.
- *artedi,* (68) 77–87 (94), with 88 per cent more than 77.

L/H:
- *hoyi,* (3.6) 4–4.2 (4.6), with 13 per cent more than 4.2.
- *artedi,* (4) 4.2–4.5 (4.6), with 66 per cent more than 4.2.

H/M:
- *hoyi,* (2.3) 2.5–2.6 (2.8), with 16 per cent more than 2.6.
- *artedi,* (2.4) 2.7–3 (3.1), with 86 per cent more than 2.6.

Av/V:
- *hoyi,* (1) 1.2–1.4 (1.7), with 8 per cent more than 1.4.
- *artedi,* (1.3) 1.5–1.7 (2), with 93 per cent more than 1.4.

In general *hoyi* has also a deeper, less terete body than *artedi,* particularly when small, and the head, as seen from the side, is more sharply pointed. The body and fins of *hoyi* are also less pigmented. The state of development of sex organs, especially in females, may often assist in separating individuals of the species, as *hoyi* spawns in March and *artedi* in November.

GEOGRAPHICAL DISTRIBUTION

In Table 56 are given all my data on the occurrence of the bloater in Lake Michigan. They are also shown platted on a map of the lake in Figure 4. There are 53 observations made by me from the 1½-inch bait nets, which catch small fish to bait the trout hooks; from the 4 to 4½ inch trout and whitefish nets, the 2⅜ to 2¾ inch chub nets, and from the pound nets. In the first two kinds of nets only small individuals are taken usually, those in the trout and whitefish nets being caught only accidentally by entangling their jaws in the netting. In the chub nets

[16] Figures in this section are given for all collected specimens, except the proportions for *artedi,* which are based on an examination of specimens less than 225 millimeters in length.

small fish are accidentally entangled also, but large numbers of larger specimens become gilled, particularly in the 2⅜ and 2½ inch nets, and are brought to the market along with the other species of Leucichthys that comprise the catches. The bloaters may even be so numerous in these nets that they are caught to the virtual exclusion of all other Leucichthys. These three types of netting are the only kinds of gill netting exployed on the lake, and some type or all types are in use out of all the fishing ports. At every port from which catches were examined from depths of more than 75 feet some specimens of the bloater have been collected, and specimens also have been taken from the pounds set in shallow water out of two ports. As these ports are well distributed along the lake's shores, it is safe to conclude that the bloater may be found throughout the lake at suitable depths.

BATHYMETRIC DISTRIBUTION

In the 1½-inch bait nets the bloaters and other small Leucichthys are taken to bait the trout hooks that are in use during most of the calendar year out of certain ports. Such nets are set during most of the season at about 26 to 40 fathoms. Catches of these nets were examined on seven occasions (see p. 354), and *hoyi* always were found (records 9, 12, 19, 27, 35, 41, and 43). A few specimens were taken by me in test nets of 1½-inch mesh lifted on July 21 and 23, 1923, in Platte Bay, Mich., from 8 to 12 and 15 to 25 fathoms, respectively, and on July 25, 1923, off Lees Point in Grand Traverse Bay from 6 to 16 fathoms (records 38, 39, and 44).

In the 2⅜ to 2¾ inch chub nets some bloaters probably always are present. They are either large enough to gill or are caught by the jaws in the netting. Taken in this fashion, specimens are recorded from chub gangs examined in March, 1919 and 1921, April, 1921, May, 1922, June, 1920, July and August, 1923, and August, September, October, and November, 1920, at depths between 18 fathoms (off Michigan City, Ind., on November 19, 1920) and 71 to 90 fathoms (off Rock Island, Wis., on August 19, 1920) (records 25 and 5).

The trout and whitefish nets of 4 to 4½ inch or larger mesh are set usually in less than 40 fathoms. No lifts of such nets ever were examined, but specimens were brought in by pilots of vessels from their large-meshed nets off Washington Harbor, Wis., 5 miles west and 3 miles WNW. of Boyer Bluff on August 18 and 19, 1920, in 20 to 24 fathoms (records 2 and 4); 30 miles NNW. of Michigan City, Ind., on November 19, 1920, in 48 to 50 fathoms (record 23); 7 miles NW. by N. of Ludington, Mich., on August 30, 1920, in 14 to 26 fathoms (record 33); 9 miles northwest of Manistee, Mich., on August 28, 1920, in 28 to 32 fathoms (record 36); and 13 miles SE. ½ E. of Manistique, Mich., on August 11, 1920, in 20 fathoms (record 51).

The bloaters of a marketable size also are said to run commonly into the pound nets in summer, at least at Port Washington on the Wisconsin shore, and specimens were taken by me in the pounds there on September 27, 1920, in 5 fathoms of water (record 13). Small individuals were found abundantly in a pound in Grand Traverse Bay at the same depth on July 26, 1923 (record 45). The University of Michigan collection contains 13 small specimens taken off Ludington, Mich., "within 150 yards of shore." These may have been taken in pounds but more probably were seined.

The data thus show that the bloater has a very wide depth range in the lake. It is known to run from shore down to depths of 90 fathoms, and it is possible that it strays to even greater depths.

RELATIVE ABUNDANCE

Data from the 1½-inch bait nets.—The bloaters are taken most abundantly in the 1½-inch bait nets. These nets do not take bloaters exclusively, but I have not seen any catches made by them in which the bloater was not the predominating species. In only five catches, however, have percentages of abundance been ascertained, namely, from 5 miles SE. by E. of Sheboygan, Wis., on September 28, 1920, in 30 to 32 fathoms (record 9); from 5 miles E. ½ S. of Port Washington, Wis., on September 25, 1920, in 30 fathoms (record 12); from 14 miles NNW. of Michigan City, Ind., on March 2, 1921, in 26 fathoms (record 27); from off Northport Point, Mich., on June 23, 1920, in 28 to 40 fathoms (record 41); and from the west arm of Grand Traverse Bay on July 18, 1923, in 30 to 40 fathoms (record 43). In lifts Nos. 9, 12, and 27 the percentage of *hoyi* was 75 to 96. In the lift off Northport and Traverse City 50 to 60 per cent of the catch was of *hoyi*.

In view of the composite nature of the catch of these nets nothing positive about the habits of the small *hoyi* can be gleaned from the testimony of the fishermen who employ them. All, however, are agreed that the best depth for bait is about 30 fathoms on very soft clay or mud bottom. Virtually all the hook fishermen interviewed agree that bait is most difficult to obtain during May, June, and July, and that it is most abundant after late fall. From the accounts of the occurrence of *hoyi* in the catches of other gear it will appear that these observations probably would apply to small *hoyi*.

Data from the 2⅜ to 2¾ inch chub nets.—It has been stated already that the summer of 1920 was very unfavorable for chub fishing (see p. 354), and therefore the conclusions given below regarding abundance are not so satisfactory as might be wished.

In any nets of larger mesh than 2½ inches only extreme examples of the species can gill, and therefore the percentages of *hoyi* taken in the chub nets from any of the Michigan ports, which use a minimum mesh of 2¾ inches for chubs, are not to be compared with those from Wisconsin and Indiana, where the mesh of such nets is usually smaller. The largest percentage taken in examined catches made by nets from Michigan ports is 22 per cent of 1,400 pounds of chubs caught on October 4, 1920, 9 miles north of Point Betsie in 60 to 70 fathoms (record 37).

Only occasional specimens occurred in the chub lifts (2¾-inch mesh) on June 22, 1920, and July 31, 1923, off Cathead light in 40 to 60 fathoms (records 40 and 42); on June 29, 1920, 5 miles N. by E. of Charlevoix, Mich., in 40 to 55 fathoms; on August 10, 1923, 8 miles NNW. of Big Rock Point and on August 11, 1923, 3 miles NW. ½ W. in 35 to 60 fathoms; on August 21, 1923, from an unknown locality (records 46, 48, 49, and 50); and on August 12, 1920, 15 miles SE. by S. ½ S. of Manistique, Mich., in 60 to 70 fathoms (record 52). They were rare also in lifts of similar nets made on August 23, 1920, 12 miles E. by S. of the Sturgeon Bay ship-channel mouth in 60 to 70 fathoms (record 6), but only 50 pounds of fish were taken in the lift.

In the lift of the 2⅜-inch nets made on August 16, 1920, 8 miles south of Green Island in Green Bay in 16 fathoms (record 53), and the lift of 2½-inch nets made on November 15, 1920, 20 miles ESE. of Milwaukee, Wis., in 28 to 35 fathoms on the spawning grounds of *zenithicus* (record 18), no *hoyi* were gilled, but a number of small individuals were caught by the jaw. Chub lifts made with 2½-inch nets on August 18, 1920, 4 miles west of Boyer Bluff in 18 to 24 fathoms took 50 per cent bloaters (record 1); on August 24, 1920, 10 miles E. by N. of Algoma, Wis., in 35 to 50 fathoms, 68 per cent (record 7); on September 25, 1920, 18 miles E. ½ S. of Port Washington, Wis., in 65 to 48 fathoms, 53 per cent (record 11);[17] on September 3, 1920, 22 miles NW. by N. ½ N. of Michigan City, Ind., in 30 to 40 fathoms, 42 per cent (record 20); on October 11, 1920, 20 miles N. by W. ¾ W. in 30 to 40 fathoms, 34 per cent (record 21); on November 19, 1920, 17 miles NNW. in 28 to 32 fathoms, 50 per cent (record 24); on March 2, 1921, 21 miles NNW. in 30 fathoms, 81 per cent (record 28); and on March 4, 1921, 15 miles NW. by N. ½ N. in 28 fathoms, 96 per cent (record 29).

Bloaters comprised 15 per cent or less of the catches of 2½-inch nets made on August 19, 1920, 20 miles E. ½ N. of Rock Island, Wis., in 71 to 90 fathoms (record 5); on September 23, 1920, 27 miles ESE. of Milwaukee, in 60 fathoms (record 16); on November 8, 1920, 18 miles NNW. of Michigan City, Ind., in 30 to 38 fathoms (record 22), and on November 19, 1920, 10 miles NNW. in 18 fathoms (record 25) and 17½ miles NW. by N. ¾ N. in 32 fathoms (record 26). Lifts 18, 22, 25, and 26 were composed largely or almost exclusively of spawning *zenithicus*, and the absence of *hoyi* is to be expected therefore. Lift 24, which was made out of Michigan City, Ind., at about the same time, and which shows 50 per cent of *hoyi*, may have been made outside the spawning area of those fish.

These records thus show that the lifts made by the 2½-inch gill nets between the depths of 18 and 50 fathoms, excepting those made on the spawning grounds of *zenithicus* in November, have percentages of bloaters between 34 and 96. The one lift from 16 fathoms in Green Bay and from 28 to 35 fathoms off Milwaukee gilled no fish of this species, and the lifts from depths of 60 fathoms or more took only occasional specimens, except that from off Point Betsie on October 4, 1920, which had 22 per cent *hoyi*. Considering the fact that nets of 2¾-inch mesh were used, the percentage is high and indicates that bloaters possibly were numerous on these grounds at that time.

Data from the pound nets.—In two localities the occurrence in the pound nets, among the herring, of numbers of fish, which from the descriptions given are probably bloaters, has been reported. At Port Washington, Wis., D. H. Smith says that in early July a good run of such fish enters his pounds. The fish sometimes remain ashore all during the month. F. C. Kimball reports 1,200 pounds of these fish on June 23, 1919, from three pound nets off Michigan City, Ind., and a lighter catch for a few days thereafter. They occur in the nets in varying numbers every year at this season, according to Mr. Kimball. Marketable bloaters were taken by me on September 27, 1920, in Mr. Smith's pound nets at Port Washington in 5 fathoms

[17] The nets in this case were set along the bank that slopes up to a large reef, and most of the *hoyi* taken were on the shoal end of the gang.

of water (record 13); and numbers of small individuals were collected on July 26, 1923, in a pound in Grand Traverse Bay (record 45). In view of these records, the fact that no other Leucichthys is known to venture so near the shore in summer (excepting *alpenæ*, which does not answer the fishermen's description) tends, in my opinion, to substantiate the identification of the fish reported above as *hoyi*.

From the data from all sources it appears that at some season of the year the bloater may be regularly common from the shore waters out to depths of 50 fathoms. In such situations it is taken abundantly by the pound nets, 1½-inch bait nets, and 2⅜ to 2¾-inch chub nets. On one occasion it has been known to be common in water deeper than 50 fathoms, but numbers of individuals may not venture often to such depths except where they are in proximity to shoals, as on the edges of banks and reefs. It is likely, furthermore, that large and small individuals have a different behavior, as on several occasions the latter occurred not uncommonly in the meshes of nets that would have gilled full-grown specimens easily if they had been present (records 18 and 52); but the population density of both classes of individuals probably fluctuates between the limits designated above.

BREEDING HABITS

The time of spawning of the species and several of its breeding areas are known. On March 20, 1919, 12 miles west of Grand Haven, Mich., in 50 to 55 fathoms, and on March 24, 1919, off Milwaukee, Wis., in 50 fathoms (records 31 and 15), such specimens as were collected from the chub nets were spent or sexually ripe. It is not known that the nets in either case were on the actual spawning grounds of the species, but they could not have been far removed. On March 2, 1921, a lift of 2½-inch gill nets made 21 miles NNW. of Michigan City, Ind., in 30 fathoms (record 28) contained 81 per cent of bloaters, most of which were spawning or nearly ripe. A lift made on March 4, 1921, 15 miles NW. by N. ½ N. of the same port in 28 fathoms had 96 per cent of bloaters (record 29).

The character of the bottom is unknown. No traces of bottom material were present on the anchor stones, and as clay is found commonly sticking to the anchors when the nets are lifted from such bottom, it may be that the bottom on this occasion was sandy. Most of the fish were ripe, and in the nets there were often two to four fish side by side in the meshes, probably having been gilled in the act of spawning or attempting to spawn. The specimens taken in the gang averaged larger than any other catch of *hoyi* seen on the lake and contained the largest individuals I have ever collected. There were fewer small individuals entangled in the netting than is usual at other seasons of the year, and possibly the small individuals have their own spawning areas. The lift of fish was very light (1,000 pounds in about 5 miles of netting, six nights out), considering the fact that the fish were spawning, and it may be that the bulk of the species was spawning on other grounds near by or had not yet come onto the grounds.

In a letter dated February 21, 1925, Lester Smith, of Port Washington, reports that large quantities of bloaters, heavy with spawn, are being taken in the shallow waters off that port. Considering probabilities, there seems to be no reason to doubt Mr. Smith's identification, and his observations may be taken to supplement my own.

The time of spawning, then, appears to be during March. It may begin in certain areas or at certain seasons even as early as late February. The species has been found spawning at a depth of 28 fathoms, but it may spawn in shallower or deeper water. The character of the bottom selected is not known. Breeding grounds are known to exist off Grand Haven, Mich.; Michigan City, Ind.; and Milwaukee and Port Washington, Wis.; but considering the wide distribution and abundance of the species, there are no doubt others to be found off most of the other ports on the lake.

Leucichthys hoyi of Lake Huron

The Lake Huron form is like the Michigan form in respect to body shape and other systematic characters, but it seldom grows so large. The largest specimen obtained in the lake measures only 221 millimeters, as compared with 265 millimeters for Lake Michigan, and only nine individuals have been seen over 200 millimeters in length, whereas in Lake Michigan such fish are taken often in commercial quantities. The principal systematic characters capable of numerical expression are compared for the two forms below:

Gill rakers on the first branchial arch:
- Michigan, (37) 41–44 (48).[18]
- Huron, (37) 40–43 (47).[19]

Lateral-line scales:
- Michigan, (60) 67–77 (84).[18]
- Huron, (63) 68–76 (84).

L/H:
- Michigan, (3.6) 4–4.2 (4.5).
- Huron, (3.5) 3.8–4.1 (4.5).

H/E:
- Michigan, (3.3) 3.7–4 (4.2).
- Huron, (3.3) 3.6–3.8 (4.2).

H/M:
- Michigan, (2.3) 2.5–2.6 (2.8).[20]
- Huron, (2.3) 2.4–2.6 (2.7).

Pv/P:
- Michigan, (1.3) 1.7–2 (2.5).
- Huron, (1.4) 1.7–1.9 (2.2).

Av/V:
- Michigan, (1) 1.2–1.4 (1.6).
- Huron, (1) 1.2–1.4 (1.7).

It appears from these figures that the two forms are quite similar and that they differ only in that the head and eye average proportionally somewhat larger in the Huron form, but these differences may well be due to inequality in size of the individuals of the groups compared.

The color in life is not conspicuously different from that of the Lake Michigan specimens. Preserved fish are also little different.

Pearl organs are developed by males in the breeding season, as evidenced by breeding fish taken at Harbor Beach, Mich., on March 15, 1919. Females probably also have pearls, but those in the collection had none, possibly having lost them by friction in transit, as did many of the males. The development is not different from that described for the Lake Michigan specimens, except that there are, on the average, fewer dorsolateral and ventrolateral scale rows, on the scales of which two or more pearls appear regularly. The pearls of the back and belly are also less scattered and more often are grouped around the free edge of the scale. It is possible,

[18] These figures for Lake Michigan are based on an examination of 1,161 specimens from 82 to 265 millimeters in length. The other unmarked figures are given for 1,024 individuals between the length limits of 82 and 199 millimeters, inclusive.

[19] These figures for Lake Huron, excepting those for H/M, which are given for 58 specimens, are based on an examination of 907 specimens between the lengths of 79 and 221 millimeters, inclusive. There are only 4 specimens less than 100 millimeters in length and only 9 over 200 millimeters, and their exclusion from the tables does not affect the range of the figures given.

[20] One hundred and eight specimens.

however, that such differences are due to the difference in size of specimens examined from the two lakes. Those from Lake Michigan were chiefly over 20 centimeters in length, while those from Lake Huron were all smaller.

VARIATIONS

Racial variations.—There appears to be a racial differentiation according to habitat in the same locality, which is manifested by rather conspicuous structural changes. Below are compared, for seven characters, five groups of specimens, two taken from depths of 30 fathoms or less, two from depths of 60 fathoms or more, and one group from Cheboygan, Mich., taken in a gang set from 35 to 50 fathoms. One group in each of the first two habitats was collected at Alpena, Mich. The others originated in other parts of the lake, but confirm the comparison. The specimens of the various groups are of comparable size.

Gill rakers on the first branchial arch

No.	30 fathoms			60 fathoms			30–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
37	2	0	2	4	1	5	1
38	7	9	16	13	4	17	0
39	11	7	18	31	10	41	7
40	19	30	49	49	23	72	6
41	27	45	72	59	36	95	17
42	34	31	65	54	44	98	18
43	16	24	40	42	27	69	16
44	7	19	26	15	12	27	8
45	1	2	3	6	3	9	1
46	-	1	1	-	4	4	3
47	-	-	-	-	1	1	1

Lateral-line scales

No.	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
63	-	-	-	-	-	-	1
64	1	-	1	-	-	-	0
65	2	2	4	3	2	5	1
66	0	5	5	2	6	8	2
67	2	5	7	2	4	6	5
68	13	6	19	15	4	19	6
69	10	14	24	8	12	20	8
70	17	14	31	29	12	41	6
71	14	7	21	24	11	35	6
72	12	25	37	32	16	48	7
73	14	21	35	27	9	36	6
74	15	21	36	28	20	48	7
75	11	18	29	29	14	43	12
76	6	12	18	18	8	26	3
77	4	7	11	8	10	18	2
78	4	3	7	10	6	16	3
79	1	5	6	11	1	12	3
80	-	1	1	4	0	4	-
81	2	2	4	3	3	6	-
82	-	-	-	0	2	2	-
83	-	-	-	0	1	1	-
84	-	-	-	1	-	1	-

L/H

Ratio	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
3.5	-	-	-	-	1	1	-
3.6	-	-	-	7	2	9	-
3.7	-	2	2	36	13	49	5
3.8	3	2	5	56	31	87	8
3.9	9	16	25	71	30	101	17
4.0	38	39	77	84	50	134	31
4.1	46	49	95	19	26	45	13
4.2	15	30	45	3	12	15	5
4.3	11	21	32	1	0	1	2
4.4	1	4	5	-	1	1	-
4.5	1	2	3	-	-	-	-

H/E

Ratio	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
3.3	0	1	1	-	1	1	2
3.4	1	4	5	10	5	15	1
3.5	5	9	14	26	27	53	13
3.6	24	35	59	62	35	97	23
3.7	41	41	82	69	41	110	22
3.8	38	40	78	56	32	88	12
3.9	12	17	29	27	17	44	6
4.0	3	22	25	14	5	19	2
4.1	-	2	2	2	2	4	-
4.2	-	-	-	2	-	2	-

Pv/P

Ratio	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
1.4	-	-	-	3	3	6	-
1.5	-	2	2	13	6	19	1
1.6	1	5	6	41	21	62	11
1.7	6	31	37	63	32	95	14
1.8	26	53	79	58	42	100	26
1.9	25	28	53	32	22	54	12
2.0	29	39	68	17	16	33	8
2.1	12	9	21	5	14	19	1
2.2	-	1	1	2	3	5	-

Av/V

Ratio	30 fathoms			60 fathoms			35–50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
1.0	-	-	-	4	1	5	-
1.1	3	2	5	36	21	57	5
1.2	19	29	48	110	48	159	20
1.3	36	49	85	68	52	120	24
1.4	32	58	90	32	28	60	25
1.5	9	24	33	8	12	20	4
1.6	2	6	8	-	-	-	1

Mandible

Length	30 fathoms			60 fathoms			35-50 fathoms, Cheboygan
	Harbor Beach	Alpena	Total	Alpena	Georgian Bay	Total	
Longer than upper	27	62	89	240	149	389	38
Equal to upper	64	99	163	23	20	43	40

The deep-water fish appear to have a proportionally larger head, longer paired fins (especially ventrals), and a longer mandible than those from the shallower waters. In most cases the 35-50 fathom group conforms to neither of the two but appears often to be intermediate, as might be expected. Whether specimens from 30 and 60 fathoms are always, at all seasons, so characterized is not known, and it is quite probable that there is a migration during the year of all schools of bloaters over a considerable bathymetric range, so that the fish taken throughout the season at a definite depth might very conceivably be of several schools.

The bloaters taken from the various ports on the lake agree, in the systematic characters examined, with one or the other of the two groups compared above, so that there is no evidence so far that there are geographical races in the lake.

Size variations.—Only nine specimens over 200 millimeters in length have been collected, and therefore the usual size groups can not be compared. It is not likely, however, that the changes correlated with growth are different for this form than for other Leucichthys in the lakes.

Specimens 110 millimeters long usually have been found to show maturing sex organs.

COMPARISONS

Hoyi is most like *kiyi* and young *artedi*. A discussion of the differences between *hoyi* and *kiyi* is given on page 440.

From the small *artedi* the bloater is distinguished by its less elongated and more bloated body shape, fewer gill rakers on the first branchial arch, fewer scales in the lateral line, and relatively longer head, eye, maxillary, and paired fins. These characters, excepting the first, are compared below:

Gill rakers on the first branchial arch:
- *hoyi*, (37) 40–43 (47),[21] with 2 per cent more than 44.
- *artedi*, (40) 45–50 (53),[22] with 89 per cent more than 44.

Lateral-line scales:
- *hoyi*, (63) 68–76 (84), with 12 per cent more than 76.
- *artedi*, (68) 76–86 (98),[22] with 86 per cent more than 76.

L/H:
- *hoyi*, (3.5) 3.8–4.1 (4.5), with 13 per cent more than 4.1.
- *artedi*, (4) 4.2–4.5 (4.8), with 89 per cent more than 4.1.

[21] The figures in this section for *hoyi* (except for H/M and H/S, which are given for 58 specimens) are based on an examination of 907 specimens ranging between 79 and 221 millimeters in length.

[22] These figures for *artedi* are given for 308 specimens ranging in length from 125 to 371 millimeters. Figures not so marked are based on an examination of 135 specimens between the lengths of 125 and 225 millimeters.

H/E:
hoyi, (3.3) 3.6–3.8 (4.2), with 16 per cent more than 3.8.
artedi, (3.6) 3.8–4 (4.4), with 66 per cent more than 3.8.

H/M:
hoyi, (2.3) 2.4–2.6 (2.7), with 7 per cent more than 2.6.
artedi, (2.5) 2.7–2.9 (3.2), with 89 per cent more than 2.6.

Pv/P:
hoyi, (1.4) 1.7–1.9 (2.2), with 21 per cent more than 1.9.
artedi, (1.7) 1.9–2.1 (2.3), with 68 per cent more than 1.9.

Av/V:
hoyi, (1) 1.2–1.4 (1.7), with 1 per cent more than 1.5.
artedi, (1.3) 1.6–1.7 (1.9), with 84 per cent more than 1.5.

On the average the mandible in *hoyi* probably is longer than the upper jaw more often than in *artedi*, and certainly it is seldom shorter, while in *artedi* it is frequently shorter. The state of development of sex organs frequently is a valuable criterion, also. Specimens of *hoyi* are found to mature sexually as small as 110 millimeters, while *artedi* usually do not mature under 160 millimeters. *Hoyi* spawns in February or March and *artedi* in November, so that the state of maturity of the sex organs also may be a character. *Hoyi*, as a rule, is much less pigmented, especially on the dorsal surface.

The distinguishing characters between *hoyi* and *johannæ*, *alpenæ*, *zenithicus*, and *nigripinnis* are, in the main, the same as described for these forms for Lake Michigan on pages 352, 366, 390, and 419, except that in the case of Huron the difference in size attained by *hoyi* and these four species is still more marked. Necessary modifications of the comparisons cited are given below:

Gill rakers on the first branchial arch:
hoyi, (37) 40–43 (47), with 3 per cent more than 44.
johannæ, (25) 27–31 (35).[23]
alpenæ, (31) 33–37 (41),[24] with 24 per cent more than 36.
zenithicus, (32) 35–37 (41),[25] with 47 per cent more than 36.
nigripinnis, (40) 46–50 (52),[26] with 83 per cent more than 44.

Lateral-line scales:
hoyi, (63) 68–76 (84), with 12 per cent more than 76.
johannæ, (67) 77–86 (91), with 92 per cent more than 76.
alpenæ, (70) 76–83 (91),[24] with 74 per cent more than 76.
zenithicus, (70) 72–81 (88),[25] with 56 per cent more than 76.
nigripinnis, (72) 77–83 (88), with 81 per cent more than 76.

Pv/P:
hoyi, (1.4) 1.7–1.9 (2.2), with 21 per cent more than 1.9.
johannæ, (1.2) 1.5–1.7 (2), with 3 per cent more than 1.9.
alpenæ, (1.6) 1.8–2 (2.4), with 41 per cent more than 1.9.
zenithicus, (1.7) 2–2.2 (2.6), with 73 per cent more than 1.9.
nigripinnis, (1.2) 1.4–1.7 (1.9).

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[23] Figures for *johannæ*, for gill rakers, are given for 441 specimens; for scales for 258 specimens. All others are based on an examination of 92 specimens ranging in length from 132 to 199 millimeters.

[24] Figures for *alpenæ*, except those for scales, are based on an examination of 204 specimens between the lengths of 131 and 209 millimeters. Figures for scales are given for 323 specimens of all sizes.

[25] Figures for *zenithicus*, except those for scales, are based on an examination of 77 specimens ranging in length from 139 to 199 millimeters. Those for scales are given for 144 specimens of all sizes.

[26] Figures given for *nigripinnis* are based on an examination of 134 specimens ranging in length from 208 to 371 millimeters.

H/E:

hoyi, (3.3) 3.6–3.8 (4.2), with 16 per cent more than 3.8.
johannæ, (3.6) 4–4.2 (4.5), with 95 per cent more than 3.8.
alpenæ, (3.6) 3.8–4.1 (4.4), with 78 per cent more than 3.8.
zenithicus, (3.5) 3.7–4.1 (4.3), with 60 per cent more than 3.8.

H/S:

hoyi, (3.5) 3.7–3.8 (4.2), with 78 per cent more than 3.6.
johannæ, (3.1) 3.3–3.5 (3.6).
alpenæ, (3.3) 3.4–3.6 (3.9), with 23 per cent more than 3.6
zenithicus, (3.5) 3.7–4.1 (4.3), with 53 per cent more than 3.6.

The ventrals in *hoyi* average shorter, possibly, than in *nigripinnis* and longer than in *alpenæ* and *zenithicus.*

Zenithicus spawns in late September and early October in Lake Huron, instead of November, as in Lake Michigan. The size at which sex organs begin to mature is less for *hoyi* than for any of the chubs, being about 110 millimeters, as compared with 220 millimeters for *nigripinnis*, 165 millimeters for *johannæ*, 160 millimeters for *alpenæ*, and 139 millimeters for *zenithicus.*

GEOGRAPHICAL DISTRIBUTION

Lake Huron proper.—The records in Table 58 (see also fig. 5), with the exception of Nos. 30, 34, and 35, are from my own observations and show that the bloater occurs off Cheboygan and Harbor Beach, Mich., in 30 to 50 fathoms in the 2¾ and 1½ inch gill nets; off Rogers, Mich., in 35 fathoms in the 2¾-inch nets; and off Alpena, Mich., in 14 to 100 fathoms in the 4½, 2¾, and 1½ inch nets. Off Tobermory, Ontario, the fishermen also report that bloaters are extremely abundant in June in the 4½-inch nets in 30 fathoms. As physical conditions apparently are no different in other portions of the lake, it is likely that the bloater occurs throughout the lake at depths of 14 to 100 fathoms.

North Channel.—According to the statements of three fishermen, the bloater is taken in the North Channel off Gore Bay Light in 20 to 25 fathoms. There is still deeper water off Meldrum Bay, in which the bloater probably also is found.

Georgian Bay.—On December 3, 1919, a 1½-inch net lifted from 15 fathoms in Colpoy Bay (record 41) had a few bloaters. This is the only record for bloaters in less than 50 fathoms for the bay, though in more than 50 fathoms they are taken in the chub nets as in Lake Huron. There is then no reason to suppose that the bloater does not occur thoughout the bay, as there are wide areas that are covered by about 30 fathoms of water.

BATHYMETRIC DISTRIBUTION

The bloater has no commercial value, and though large numbers often become entangled by the jaws in the chub nets and in the trout and whitefish nets, they are never brought to market. However, nets are set for them in American waters by the hook fishermen, who use them as bait for the trout hooks. These nets are of 1½-inch mesh and are set at about 30 fathoms throughout the fishing season, which for the hook fishermen embraces virtually the entire calendar year with the exception of the closed season for trout.

1. *Data from the 1½-inch bait nets.*—On Lake Huron there were two ports from which such nets were operated in 1917—Alpena and Harbor Beach, Mich.

Records 8, 22, 32, and 33 were made from these nets in 1917 and 1919. I also lifted a 1½-inch net set at other depths on three occasions with the chub gangs—off Cheboygan, Mich., on October 15, 1919, on the spawning grounds of *zenithicus* in 35 to 50 fathoms (record 4); off Alpena on September 13, 1919, in 60 fathoms (record 21); and in Colpoy Bay on December 3, 1919, in 15 fathoms on the spawning grounds of *alpenæ* (record 41). Bloaters were taken in all sets.

2. *The 2¾ to 3 inch chub nets.*—Bloaters were taken in the chub nets in Lake Huron in 35 to 50 fathoms from off Cheboygan on July 21, September 29, and October 1, 1917 (records 1, 2, and 3); from off Rogers, Mich., in 35 fathoms on October 14, 1917 (record 5); from off Alpena in 60 to 100 fathoms on August 13 and September 12, 14, 18, 19, 20, and 21, 1917, and September 13 and 18, 1919, June 30 and July 2, 5, and 7, 1923 (records 6, 10, 11, 14–18, 21, and 24–28); from off Harbor Beach, Mich., in 50 fathoms on October 27, 1917 (record 31); and in Georgian Bay in 52 to 70 fathoms off Lions Head on July 30 and October 6, 1919 (records 36 and 37), off Wiarton on July 28 and 30, 1919, and in 10 to 25 fathoms on November 28, 1919 (records 38, 39, and 40).

3. *The 4½-inch trout and whitefish nets.*—The records for the 4½-inch nets made from boats fishing off Alpena, Mich., show bloaters at depths of 15 to 24 fathoms in 1917 on September 7, 12, 14, 17, 22, and 26; in 20 to 30 fathoms on September 16, 1919; and in 14 to 20 fathoms in 1923 on July 10 (records 7, 9, 12, 13, 19, 20, 23, and 29). They are also reported from off Alpena, Mich., in 24 to 30 fathoms in the 4½-inch nets in November (record 30); from off Tobermory, Ontario, in 30 fathoms in June (record 34); and from off Gore Bay Light in the North Channel in August in 20 to 25 fathoms (record 35).

4. *Seines.*—The University of Michigan collection contains two small specimens that were seined in the spring of 1926 off Port Huron, Mich., with *Notropis atherinoides*.

These data thus show that bloaters become ensnarled in the chub and trout nets in water as shallow as these nets usually are set, namely, 14 fathoms, and in the chub nets as deep as these usually are set (100 fathoms), and that they also may occur in seine hauls made on the beaches. The species probably occurs in depths of more than 100 fathoms.

RELATIVE ABUNDANCE

The hook fishermen have found that at only about 30 fathoms can bloaters be taken in numbers sufficient for their purposes. John Hollander, a hook fisherman at Harbor Beach, tells me that from August 1 until the middle of October, when the bait nets are pulled in, bait is scarce anywhere. It is particularly rare during the first half of this period. He says he is unable to find the fish by moving the nets into deeper water or into shallower water. When the nets are put back on November 1 the bloaters are abundant until March. Then for a month they are scarce. There is no explanation for this scarcity except by assuming that the fish are swimming off the bottom, or that they have migrated to distant grounds, or that for some reason they avoid the netting.

I have stated already that bloaters are caught only by accident in the nets of mesh coarser than 1½ inches, but that, nevertheless, great numbers are often caught in the 2¾ and 4½ inch nets. I have pointed out before that nothing is known

about the conditions under which small fish become ensnarled in such netting, and therefore the number of bloaters taken by nets too large to gill them may be no accurate gauge of their abundance. The same, however, may be said of nets in which they could gill, and for the present it seems worth while to record the relative abundance of the fish captured accidentally, particularly when the results are fairly constant and are supported by data obtained from the 1½-inch nets, which must be considered as a more effective apparatus of capture and therefore likely to yield more reliable evidence of abundance.

Only on one occasion did I see bloaters numerous in the large-meshed nets, namely, on October 14, 1917, off Rogers, at the 35-fathom end of a 2¾-inch chub gang (record 5). Only occasional specimens occurred in nets at that depth off Cheboygan on July 21, September 29, and October 1, 1917 (records 1, 2, and 3), and conditions obviously were unsuitable for their capture. However, the fishermen report bloaters in such numbers in their trout nets as to be a nuisance. Off Tobermory in June in 30 fathoms and off Alpena in November in 24 to 30 fathoms (records 30 and 34) the bloaters are said to be so abundant in the 4½-inch nets that it requires several hours to clear the nets of them. The fishermen then often turn the steam hose on the nets to cook the fish and afterwards remove them by shaking the nets.

At other situations bloaters have not been seen or reported to be caught abundantly in large-meshed nets. Only few or occasional specimens were taken in the lifts of the 2¾ to 3 inch chub nets from 60 to 100 fathoms made in Lake Huron off Alpena, Mich., on August 13 and September 12, 14, 18, 19, 20, and 21, 1917, September 13 and 18, 1919, and June 30, and July 2, 5, and 7, 1923 (records 6, 10, 11, 14–18, 21, and 24–28); from 50 fathoms off Harbor Beach, Mich., on October 27, 1917 (record 31); and in Georgian Bay in 52 to 70 fathoms off Lions Head on July 30 and October 6, 1919 (records 36 and 37), off Wiarton on July 28 and 30, 1919, and in 10 to 25 fathoms on November 28, 1919 (records 38, 39, and 40). It is not known that bloaters ever are absent entirely from such lifts, though it is conceivable that they might be. In August, at 20 to 25 fathoms, they are said to be common in the 4½-inch nets off Gore Bay in the North Channel (record 35). During September, 1917, off Alpena, bloaters were brought in not infrequently from the 4½-inch gangs in 15 to 24 fathoms. The total number of fish taken from these gangs on these dates was not great, but the relative number of the species taken by them at various depths is significant. For example, at 24 fathoms (record 12) 52 specimens were taken; at 16 to 20 fathoms (record 7) 19 specimens; at 17 fathoms (records 19 and 20) 20 and 3 specimens; at 15 to 17 fathoms (record 9) 4 specimens; and at 15 fathoms (record 13) 2 specimens. An unknown number of specimens was caught in the 4½-inch nets off Alpena on September 16, 1919, in 20 to 30 fathoms, and on July 10, 1923, in 14 to 20 fathoms (records 23 and 29). The data in this paragraph receive additional significance when the captures of the special 1½-inch nets referred to on page 463 are considered. The set made off Cheboygan in 35 fathoms captured bloaters abundantly. Off Presque Isle Light, Mich., in 60 fathoms, only 112 specimens were taken, which under the conditions of the set indicates few fish in that area; and in Georgian Bay off Wiarton, in 15 fathoms, only 25 fish were gilled, likewise indicating a rarity of the species. The results in the last-named case may have been influenced by the presence of *alpenæ*, which had been spawning on the grounds.

The data reviewed indicate that the bloater can be captured most abundantly at depths of about 30 fathoms, though at times it may be relatively uncommon at that depth. Numerous individuals often become entangled in large-meshed nets at that depth, and occasional specimens are known from these nets between 10 and 100 fathoms. It appears that the abundance of the species decreases toward the extremes of the zone of distribution.

BREEDING HABITS

Not even the hook fishermen know when the fish spawn. The same opinion as to the spawning season is held for the bloaters as for the chubs, namely, that they spawn all the year round. However, there is no evidence to support such a belief except that eggs are found in the fish during most of the season; but these eggs are not ripe when found. Specimens taken on December 3, 1919, in Colpoy Bay and on December 9, 1917, at Harbor Beach were not yet ripe. On March 14, 1919, Mr. Hollander wrote me from Harbor Beach that bloaters were then very scarce. Fish of this species which he collected for me on March 15 were spent females and pearled males. As the males are not found with pearls later in the year, it is certain that these fish had been on the spawning grounds a short time previous to March 15 (probably in February), and that for this reason they are scarce in March in the bait nets at 30 fathoms. At what depth and on what bottom they spawn is not known.

FOOD

Doctor Hubbs has examined the contents of 26 stomachs of specimens taken off Alpena, Mich., in September, 1917 and 1919, in 30 fathoms or less, and of 36 specimens from 60 fathoms and deeper, of 42 stomachs from specimens taken off Cheboygan, Mich., on October 15, 1919, and 1 taken in Georgian Bay on July 30, 1919.

The shallow-water specimens from Alpena had eaten from 60 to 98 per cent Pontoporeia. Almost all stomachs contained Pisidium more or less abundantly, and also wood and seed fragments. Sand, cinders, adult-insect remains, and Mysis were found occasionally. Stomachs of the deep-water fish from Alpena showed that Mysis constituted almost the sole food. Six stomachs had Pontoporeia and nine fragments of wood. Pisidium, insect larvæ, sand, or pebbles were found in very small quantities in occasional stomachs. The Georgian Bay fish (also from deep water) had eaten only Mysis.

The Cheboygan specimens from intermediate depths had eaten Mysis more frequently than Pontoporeia. Some stomachs had predominantly the one, some the other, but both forms occurred in most, indicating (in view of the rarity of Mysis and the abundance of Pontoporeia in the stomachs of the Alpena fish from 30 fathoms or less, and the reversed ratio in the stomachs of those from 60 fathoms or more) that the zones of distribution of the two forms overlap at about 35 fathoms. Pisidium and vegetable fragments are also frequent articles in the Cheboygan stomachs, and the casually swallowed items are the same as those given in the previous paragraph. In addition, Leucichthys eggs occurred in 10 of the stomachs, usually in small numbers, except that they comprised 94 per cent of the contents of one stomach.

(These eggs undoubtedly were of *zenithicus*, as the bloaters were taken on the spawning grounds of this species.) One fish had eaten chiefly wheat, one had found bryozoan statoblasts, and one contained a fish scale.

It seems that the bloater will eat whatever occurs in his environment. It is possible that the species feeds heavily on fish spawn.

Leucichthys hoyi of Lake Superior

The bloater of Lake Superior resembles the Michigan form in shape and general appearance, but apparently it does not grow so large. The largest individual collected measures 251 millimeters, but specimens over 200 millimeters were taken rarely, though nets that would have gilled them were set in many situations in the lake where their presence might have been expected. (See p. 382.) The systematic characters of the two forms that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (37) 41–44 (48).[27]
- Superior, (37) 41–44 (49).[28]

Lateral-line scales:
- Michigan, (60) 67–77 (84).[27]
- Superior, (65) 69–78 (84).[28]

L/H:
- Michigan, (3.6) 4–4.2 (4.5).
- Superior, (3.4) 3.7–4 (4.2).

H/E:
- Michigan, (3.3) 3.7–4 (4.2).
- Superior, (3.2) 3.6–3.8 (4).

H/M:
- Michigan, (2.3) 2.5–2.6 (2.8).
- Superior, (2.2) 2.3–2.5 (2.7).

Pv/P:
- Michigan, (1.3) 1.7–2 (2.5).
- Superior, (1.4) 1.5–1.8 (2).

Av/V:
- Michigan, (1) 1.2–1.4 (1.6).
- Superior, (0.9) 1.1–1.3 (1.6).

These figures indicate that the Superior form has a proportionally larger head and eye and longer paired fins and maxillary. There are also, on the average, slightly fewer scale rows around the body at the various points of count.

The color in life is about the same in the two forms except for minor details of pigmentation. Superior specimens appear, on the average, to be a trifle more pigmented. The anal fin, especially, is as often with some pigment as it is immaculate.

No individuals were taken during the breeding season, so that nothing is known about the development of pearl organs. Very probably they are developed as in others of the Great Lakes Leucichthys and likely are not different from those described for the typical form.

VARIATIONS

Racial variations.—Most of the specimens were collected from off the Apostle Islands, and there is no sufficient number of specimens comparable in size taken from any other locality for comparison. No material is available either to determine whether there are any shallow-water and deep-water races occurring out of the same port. In view of the fact that the transition to deep water is abrupt almost every-

[27] These figures for Lake Michigan are based on an examination of 1,161 individuals from 82 to 265 millimeters in length. The other figures for Lake Michigan are given for 1,024 specimens between the limits of 82 and 199 millimeters, except the H/M values, for which 108 specimens were measured.

[28] These figures for Lake Superior are based on an examination of 335 specimens ranging in length from 107 to 251 millimeters. Figures dealing with proportions, excepting those for H/M (which are based on 61 specimens), are given for 291 specimens from 107 to 199 millimeters in length.

where in Lake Superior, there would be room for such raciation, but the bloaters seem to be most common along these banks and seldom are found below them.

Size variations.—In Table 61 five individuals 200 millimeters or longer are compared extensively with five shorter. Below are given values for certain characters for 44 specimens over 200 millimeters in length and 291 smaller ones:

L/H:
- Large specimens, (3.7) 3.9–4.1 (4.3).
- Small specimens, (3.4) 3.7–4 (4.2).

H/E:
- Large specimens, (3.7) 3.9–4 (4.3).
- Small specimens, (3.2) 3.6–3.8 (4).

Pv/P:
- Large specimens, (1.4) 1.7–2 (2.2).
- Small specimens, (1.4) 1.5–1.8 (2).

Av/V:
- Large specimens, (1.1) 1.2–1.4 (1.5).
- Small specimens, (0.9) 1.1–1.3 (1.6).

It appears, as is usual, that the head, eye, and paired fins become proportionally shorter with growth.

Individuals over 130 millimeters in length usually have been found to be sexually mature.

COMPARISONS [29]

The characters that separate *hoyi* from *kiyi* (to which it most nearly approaches) are given on page 443. A discussion of the differences between *hoyi* and *zenithicus* is given on page 381, between *hoyi* and *reighardi* on page 411, and between *hoyi* and *nigripinnis* on page 427.

From *artedi*, *hoyi* is distinguished chiefly by the fewer gill rakers on the first branchial arch, fewer lateral-line scales, larger head and eye, longer paired fins and maxillary, and by the mandible, which in *hoyi* is hooked and usually longer than the upper jaw, while in *artedi* it is seldom hooked and usually equal or shorter. The aforementioned characters, which can be expressed numerically, are compared below:

Gill rakers on the first branchial arch:
- *hoyi*, (37) 41–44 (49), with 10 per cent more than 44.
- *artedi*, (38) 45–48 (53), with 87 per cent more than 44.

Lateral-line scales:
- *hoyi*, (65) 69–78 (84), with 7 per cent more than 78.
- *artedi*, (72) 84–93 (105), with 92 per cent more than 78.

L/H:
- *hoyi*, (3.4) 3.7–4 (4.3), with 11 per cent more than 4.
- *artedi*, (4) 4.2–4.6 (4.8), with 97 per cent more than 4.

H/E:
- *hoyi*, (3.2) 3.6–3.8 (4.3), with 18 per cent more than 3.8.
- *artedi*, (3.4) 4–4.2 (4.5), with 84 per cent more than 3.8.

H/M:
- *hoyi*, (2.2) 2.3–2.5 (2.7), with 6 per cent more than 2.5.
- *artedi*, (2.5) 2.7–3 (3.2), with 99 per cent more than 2.5.

Pv/P:
- *hoyi*, (1.4) 1.5–1.8 (2.2), with 11 per cent more than 1.8.
- *artedi*, (1.6) 1.9–2.2 (2.3), with 74 per cent more than 1.8.

Av/V:
- *hoyi*, (0.9) 1.1–1.3 (1.6), with 10 per cent more than 1.3.
- *artedi*, (1.4) 1.5–1.8 (1.9).

[29] Figures given in this section are based on all collected specimens, except for proportions of *artedi*, which are based on specimens less than 225 millimeters long.

The body shape of *hoyi* is also less elongated, the flesh is softer, and the color is likely to be paler. The state of the sex organs also may serve to separate the smaller individuals, as *hoyi* matures at about 130 millimeters while few *artedi* are mature under 200 millimeters.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of *hoyi* in Lake Superior are given in Table 60. They are shown in Figure 3 platted on a map of the lake. The 16 records were made chiefly from nets of 2½ to 4½ inch mesh, in which individuals were ensnarled accidentally; but on two occasions the catches of the 1½-inch bait nets were examined. There are sufficient data to warrant the conclusion that the bloater occurs throughout Lake Superior and even in the north bays where suitable conditions are found.

BATHYMETRIC DISTRIBUTION

Only by the use of 1½-inch nets can it be ascertained definitely what are the limits of the bloater's zone of distribution. No lifts of these nets were seen by me from less than 40 fathoms. Nets of 2½ to 4½ inch mesh were lifted on several occasions from shallower water, and in several such gangs bloaters were caught. They were not present in two lifts of such nets made in September from 11 and 14 fathoms, but occurred in several lifts set as shallow as 15 to 20 fathoms. From depths of more than 40 fathoms, where the nets were set on a bank and extended from shallow water to depths of 90 fathoms, specimens were taken in the 1½ to 4½ inch nets. The only specimens taken in depths of 80 to 90 fathoms, where such depths did not occur immediately at the foot of a bank, were caught in a lift made off Bread Rock, Ontario, on October 4, 1921, in 80 to 90 fathoms (record 15). Five other lifts of gangs of such nets made off Grand Marais and Marquette, Mich., Michipicoten Island and Coppermine Point, Ontario (see Table 24), from depths of 60 to 100 fathoms, took no bloaters among the small fish accidentally captured.

It is likely, then, that the bloater ranges along the banks down to depths of 90 fathoms but does not wander out into the vast areas that are covered by such depths. How close to shore it goes is not known, but in summer specimens have been taken as shallow as 15 fathoms.

RELATIVE ABUNDANCE

In Lakes Michigan and Huron the species appears to prefer depths of about 30 fathoms for the greater portion of the year, but in Lake Superior there are very restricted areas of shoal water and the descent from shore to the plains (which are overlaid by depths of 60 to 100 fathoms and more) is abrupt. It is on these banks that the species has been found most abundantly. Thus, in the 4½-inch nets, which in the 2 or 3 miles of their length extended from depths of 40 to 90 fathoms, specimens were occasionally or commonly found entangled, namely, on July 14, 1922, 25 miles north of South Twin Island, Wis.; on July 15, 1922, 14 to 18 miles NW. by N. of South Twin Island and 20 miles northwest of Rocky Island, Wis.; and on September 14, 1921, and July 17, 1922, off Terrace Point, Minn. (records 6, 7, 8, 10, and 11). Occasional specimens were taken similarly on August 24, 1921, 21 miles west, and on August 25, 1921, 6 miles NNW. of Ontonagon, Mich., in 15 to 45 and 20 to 38 fathoms, respectively; on July 17, 1922, 20 miles NE. by E. of Duluth,

Minn., in 30 to 40 fathoms (record 9); in Thunder Bay on September 15, 1923, inside Thunder Cape in 31 fathoms; on September 17, 1923, inside the Welcome Islands in 23 fathoms; on September 19, 1923, off Sawyer Bay in 49 fathoms; and on September 29, 1923, off Salter Island in 42 fathoms (records 3, 4, 12, 13, 14, and 16). Only one specimen was found in the 2½ and 2¾ inch nets lifted on July 11, 1922, between Cat and South Twin Island in 15 to 20 fathoms (record 5), and two were taken on October 4, 1921, off Bread Rock in 80 to 90 fathoms (record 15). None occurred in the lifts of gangs of 3 to 10 miles of 4½-inch nets lifted on October 3, 1917, off Grand Marais, Mich., in 65 fathoms and deeper; on August 5 and 11, 1921, 31 miles N. ¾ E. and 18 miles NE. by N. of Marquette, Mich., in 80 to 100 fathoms; on June 26, 1922, off Alona Bay, Ontario, in 60 fathoms, and on June 19, 1922, 6 miles northeast of the east end light of Michipicoten Island in 15 to 35 fathoms. Small stretches of the special 2½ to 2¾ inch nets lifted on several occasions from 11 to 80 fathoms had no fish of this species. The lifts of large-meshed nets, in which small fish become entangled, of course, can offer no conclusive data on their abundance in the vicinity of such nets, as it is not known under what conditions these fish become entangled in the netting. It is interesting in this connection, however, to point out that in the gangs mentioned above, lifted off Grand Marais, Mich., on October 3, 1917, off Marquette, Mich., on August 5 and 11, 1921, and off Alona Bay, Ontario, June 26, 1922, small *kiyi* and *zenithicus* were ensnarled; and it is at least probable that *hoyi*, had they been present, would have been taken in the same manner. In the 1½-inch bait nets lifted on June 14, 1922, in Whitefish Bay from 40 to 50 fathoms (record 1) and on August 8, 1921, 6 miles NE. ¾ N. of Marquette, Mich., from 42 to 65 fathoms (record 2), the species was fairly common. The hook fishermen, however, are not able continually to find enough bait for their hooks at those depths, but often are forced to set them nearer shore, where they probably take other species of fish.

Concerning the proportion of other fish that occur in the bait nets nothing is known. It is very likely, however, that small *zenithicus* are taken regularly among the bloaters at depths of 40 to 50 fathoms. *Kiyi* probably does not come so shallow often and *artedi* seldom so deep.

The data thus indicate that the bloater occurs most abundantly along the banks that border the deep-water plains. Specimens have been taken as shallow as 15 and as deep as 80 or 90 fathoms, but they are commonest, so far as is known, between he depths of 35 and 50 fathoms.

BREEDING HABITS

Nothing is known about the breeding habits of the species except that the specimens taken up to October 4, 1921, showed no mature ovaries. Occasional females that had ova rather larger than those of their companions have been taken during the summer at several ports, and it might be expected that these individuals would spawn earlier than the rest. It is not certain, however, that the ova would ripen prematurely even though their growth was precocious originally. Fishing operations usually are suspended from early December until spring, so that unless the fish spawn before December (which they probably do not) the time and place of their spawning will not be determinable readily.

Leucichthys hoyi of Lake Nipigon

The bloater of Lake Nipigon has the same general form of body as the Lake Michigan race, but there are average differences in the proportional lengths and in the number of some of the multiple parts. It appears, however, that the species does not commonly grow so large as in Lake Michigan. In virgin waters only 13 specimens over 200 millimeters in length were obtained, and the largest specimen measured only 231 millimeters, whereas in Lake Michigan examples of over 200 millimeters are very common and the maximum recorded size is 265 millimeters. The most conspicuous characters of the two forms are compared below:

Gill rakers on the first branchial arch:
- Michigan, (37) 41–44 (48).[30]
- Nipigon, (40) 42–46 (48).[31]

Lateral-line scales:
- Michigan, (60) 67–77 (84).[30]
- Nipigon, (66) 73–80 (85).[31]

L/H:
- Michigan, (3.6) 4–4.2 (4.5).
- Nipigon, (3.6) 3.8–4 (4.2).

H/E:
- Michigan, (3.3) 3.7–4 (4.2).
- Nipigon, (3.1) 3.6–3.8 (4).

H/M:
- Michigan, (2.3) 2.5–2.6 (2.8).
- Nipigon, (2.2) 2.3–2.4 (2.5).

Pv/P:
- Michigan, (1.3) 1.7–2 (2.5).
- Nipigon, (1.2) 1.4–1.7 (1.9).

Av/V:
- Michigan, (1) 1.2–1.4 (1.6).
- Nipigon, (1) 1.1–1.3 (1.5).

It appears, thus, that the Nipigon form tends to have a slightly higher average number of gill rakers on the first branchial arch and of scales in the lateral line, and a proportionally longer head, eye, maxillary, and paired fins. The number of dorsal rays also tends to become greater. The usual range is not changed, but there are more specimens that register in the upper limits. The scale rows around the body average fewer, the branchiostegals more, the mandible longer, and the height of the anal fin in proportion to its base length (AC) averages greater; that is, the rays are longer. For some values for most of these characters, see the detailed comparison of 10 specimens from each lake given in Tables 57 and 63.

The color in life was not recorded but probably is not different from that of the Michigan form. Alcoholic specimens show, in general, less pigment than the typical form. The distribution of the pigment on the body is about the same, but the pigment dots on the dorsal surface usually are fewer and rather coarser, and the pectoral and anal fins, as well as the ventrals, are usually immaculate. Even the dorsal and caudal may be very pale but usually are smoky. The maxillary, which is always pigmented in the Lake Michigan form, may be immaculate, also, but usually shows more or less of pigment over its proximal half.

No specimens were seen ready to spawn, so that it is not known to what extent pearl organs are developed. The nuptial dress probably is no different from that described for the Lake Michigan form.

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[30] These figures for Lake Michigan are based on an examination of 1,161 individuals from 82 to 265 millimeters in length. The other figures are given for 1,024 specimens less than 200 millimeters long, except the H/M value, for which 108 specimens were measured.

[31] These figures for Lake Nipigon are based on an examination of 174 specimens ranging in length from 106 to 231 millimeters. The other figures, except those for H/M, which are based on 82 specimens, are given for 158 specimens less than 200 millimeters long.

VARIATIONS

Racial variations.—Not enough specimens have been collected to determine whether there is more than one race in the lake. There are no indications, however, from the material obtained from several localities that such races, if they exist, are marked by conspicuous external features.

Size variations.—Only 13 specimens longer than 200 millimeters were obtained. Five of these are extensively compared in Table 63 with five under 200 millimeters. The meager data of this table indicate little, but it is likely that the usual changes of growth obtain, namely, that large fish tend to have a proportionally smaller head and eye and shorter paired fins.

Individuals have been found approaching sexual maturity at 134 millimeters, but some specimens below 157 millimeters show no indications of spawning during the year. Beyond the last-named limit, all specimens were found to be maturing.

COMPARISONS [32]

A discussion of the differences between *hoyi* and *zenithicus, reighardi,* and *nigripinnis* is given on pages 386, 408, and 432.

From *artedi* and *nipigon, hoyi* is distinguished by its longer mandible, fewer gill rakers on the first branchial arch, and longer maxillary. Certain of these characters are compared below:

Gill rakers on the first branchial arch:
- *hoyi,* (40) 42–46 (48), with 4 per cent more than 46.
- *artedi,* (41) 46–49 (53), with 74 per cent more than 46.
- *nipigon,* (54) 56–59 (66).

H/M:
- *hoyi,* (2.2) 2.3–2.4 (2.5), with 13 per cent more than 2.4.
- *artedi,* (2.6) 2.7–2.8 (3).
- *nipigon,* 2.5–2.7 (3.1).

Hoyi is also much less pigmented than the others and has a larger head than *artedi.* The specimens of *nipigon* are too large for comparison with those of *hoyi* in this character.

GEOGRAPHICAL DISTRIBUTION

All the data for the specimens of the species that I have examined from Lake Nipigon are given in Table 62 and are shown platted on the map of the lake in Figure 2. They are derived from the various apparatus that has been used on the lake. The places from which bloaters have been collected are sufficiently scattered over the lake to justify the conclusion that they occur throughout its extent where suitable ecological conditions obtain.

DEPTH DISTRIBUTION

The only nets employed by me in Lake Nipigon were the 2½ and 2¾ inch gill nets and in these no *hoyi* were gilled, but such specimens as they took became

[32] Values in the comparison are given for all the collected specimens.

ensnarled in the netting. Numbers of bloaters are taken in the same manner in the 4½-inch whitefish nets, and all the specimens listed in Table 62 probably were caught in gear of these types. Through the use of these nets alone nothing definite can be ascertained about the depth range of the species, as the capture of individuals is accidental; and, moreover, it is very likely that they also took bloaters, when set at other depths, of which no record was made. The records, however, show no specimens in less than 15 fathoms, from which nets were lifted on August 1, 1922, in Ombabika Bay and on July 29, 1924, in Orient Bay (records 9 and 4). The set lifted on September 3, 1923, in Humboldt Bay, which took a number of bloaters, extended from 6 to 35 fathoms and obviously was set on a bank (record 7), but it is not known that any fish were caught at the shallow end of the gang. The deepest record is the capture of specimens on July 25, 1924, off Blackwater River in 54 fathoms (record 6). Present data, therefore, indicate that the bloater ranges between the depths of 15 and 54 fathoms, but these data do not fix the limits of the zone of distribution.

RELATIVE ABUNDANCE

The only criterion of the abundance of the species is the frequency of the accidental captures of specimens in the nets set for other species. On July 26, 1922, off Macdiarmid in 30 fathoms (record 1) bloaters were common. In another lift of the same kind and quantity of netting made by me on July 25, 1922, off the source of the Nipigon River in 10 to 15 fathoms, and in a lift made with half the quantity of netting on July 28, 1922, 2½ miles south of Livingston Point in 56 fathoms, no specimens were taken. No statements of frequency of occurrence accompany the records in Table 62, and in the absence of more information on this point no conclusions can be drawn, but it is interesting that the one observation suggests that the depth preference may be as in Lake Michigan.

BREEDING HABITS

Nothing is known about the time or place of spawning of the species. Specimens were taken only between July 25 and October 26. Those on the earliest date had not spawned recently, and those on the latest were not yet ripe. Two females had ova in a considerably more advanced state of development than the rest and apparently were nearly ripe, but the 15 other specimens showed no indications that they would spawn soon. Occasional females with ova larger than those of the bulk of the race were found among the specimens collected during the summer, and a similar condition has been reported for the species in Lake Superior. (See p. 469.)

Leucichthys hoyi of Lake Ontario

The bloater of Lake Ontario is like that of Lake Michigan in respect to general appearance and to the size commonly attained. The largest example collected measured 277 millimeters, as compared with 265 millimeters, which is the largest specimen from Lake Michigan; but as in Lake Michigan, very few fish over 250 millimeters were collected. The important systematic characters of the two forms are compared below:

Gill rakers on the first branchial arch:
- Michigan, (37) 41–44 (48).[33]
- Ontario, (39) 42–47 (50).[34]

Lateral-line scales:
- Michigan, (60) 67–77 (84).[33]
- Ontario, (63) 67–76 (82).[34]

L/H:
- Michigan, (3.9) 4.1–4.3 (4.6).
- Ontario, (3.8) 4–4.2 (4.6).

H/E:
- Michigan, (3.8) 3.9–4.1 (4.5).
- Ontario, (4) 4.1–4.4 (4.7).

H/S:
- Michigan, (3.5) 3.6–3.9 (4.1).[35]
- Ontario, (3.4) 3.6–3.8 (4.1).[36]

H/M:
- Michigan, (2.3) 2.5–2.6 (2.8).[37]
- Ontario, (2.4) 2.5–2.7 (2.8).[38]

Pv/P:
- Michigan, (1.6) 1.8–2.1 (2.3).
- Ontario, (1.4) 1.7–2 (2.2).

Av/V:
- Michigan, (1.1) 1.3–1.5 (1.7).
- Ontario, (1.1) 1.3–1.5 (1.6).

Mandible compared with upper jaw:
- Michigan, equal 326, longer 726.
- Ontario, equal 52, longer 199.

From these data it appears that the Ontario form has, on the average, rather more gill rakers on the first branchial arch, a proportionally smaller eye, and possibly a somewhat longer head and pectorals. The mandible seems to project more often beyond the upper jaw in Ontario specimens. The body of Ontario specimens, on the whole, is also slightly more elongated and more compressed than in the Michigan specimens, especially in the larger ones, which in Michigan often become conspicuously wide. In other matters, as fin rays, scale rows, etc., the two forms are in virtual agreement.

The color in life is not conspicuously different from that of the Michigan race, except that pigmentation usually is more extensive and intensive. Alcoholics often show those areas that are most pigmented in the Michigan form (as the entire dorsal surface, the preorbital area, and mandible tip) conspicuously dark, and pigment usually extends farther on the sides, even to below the lateral line. The fins also are darker, except the ventrals, which remain immaculate. The anal more often shows pigment dots on its membranes, and the pectorals always show at least some pigment but usually not more than a lining of black on the dorsal edge.

The males, at least, develop pearl organs in the breeding season. Only one pearled fish has been collected, and many of the excrescences on it have been removed by friction, but from those remaining I conclude that the development of the breeding adornment probably is not different from that described for the Michigan form.

VARIATIONS

Racial variations.—No differences are observable between the groups of specimens collected from the various parts of the lake, but it is not improbable that, if sufficient numbers were gathered together, local races might be differentiated. No material is available, either, to determine whether the depth inhabited affects the orm of the body and its parts.

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[33] Figures so marked for Lake Michigan are based on an examination of 1,161 specimens ranging in length from 82 to 265 millimeters. All undesignated figures are given for 137 individuals ranging between the lengths of 200 and 265 millimeters.

[34] Figures so marked for Lake Ontario are based on an examination of 258 specimens ranging in length from 128 to 277 millimeters. Undesignated figures are given for 236 specimens ranging in length from 200 to 277 millimeters.

[35] Seventy-five specimens.

[36] Two hundred and fifteen specimens.

[37] One hundred and eight specimens.

[38] One hundred and thirteen specimens.

Size variations.—By far the majority of specimens collected have been gilled in 2½-inch nets and therefore are longer than 200 millimeters. Five individuals over 200 millimeters in length and five smaller are extensively compared in Table 65. It appears that the larger specimens tend to have a proportionally smaller head and eye, more body depth, and possibly shorter paired fins.

The smallest specimen collected measured 128 millimeters and was a female with maturing ova.

COMPARISONS

Hoyi approaches both *kiyi* and *artedi* rather closely, but usually may be separated from *artedi* by a consideration of several characters. *Hoyi* has a relatively longer maxillary, snout, paired fins, mandible, head, and eye, and the body is more compressed as a rule and less elongated. The mandible also is frailer in *artedi* and seldom shows the symphysial knob of *hoyi*. The shortness of the mandible alters the shape of the head, which, seen from the side, is less sharply triangular in *artedi*. Characters that are of taxonomic use and that can be expressed numerically are given for the two species below: [39]

Gill rakers on the first branchial arch:
- *hoyi*, (39) 42–47 (50), with 4 per cent more than 47.
- *artedi*, (41) 46–50 (54), with 52 per cent more than 47.

Lateral-line scales:
- *hoyi*, (63) 67–76 (82), with 8 per cent more than 76.
- *artedi*, (66) 73–82 (89), with 54 per cent more than 76.

L/H: [40]
- *hoyi*, (3.8) 4–4.2 (4.6), with 18 per cent more than 4.2.
- *artedi*, (3.7) 4.3–4.7 (4.9), with 89 per cent more than 4.2.

H/E: [40]
- *hoyi*, (4) 4.1–4.4 (4.7), with 12 per cent more than 4.4.
- *artedi*, (3.9) 4.1–4.4 (4.9), with 22 per cent more than 4.4.

H/M:
- *hoyi*, 2.5–2.7 (2.9), with 10 per cent more than 2.7.
- *artedi*, (2.5) 2.7–2.9 (3.3), with 60 per cent more than 2.7.

H/S:
- *hoyi*, (3.4) 3.6–3.8 (4), with 16 per cent more than 3.8.
- *artedi*, (3.4) 3.7–4 (4.5), with 47 per cent more than 3.8.

Pv/P:
- *hoyi*, (1.4) 1.7–2 (2.2), with 8 per cent more than 2.
- *artedi*, (1.7) 1.9–2.1 (2.5), with 38 per cent more than 2.

Av/V:
- *hoyi*, (1.1) 1.3–1.5 (1.6), with 7 per cent more than 1.5.
- *artedi*, (1.3) 1.5–1.8 (2), with 72 per cent more than 1.5.

Mandible compared with upper jaw:
- *hoyi*, shorter 5 equal 47 longer 199 or 79 per cent longer.
- *artedi*, shorter 130 equal 121 longer 77 or 23 per cent longer.

A discussion of the differences between *hoyi* and *kiyi* is given on page 446 and between *hoyi* and *reighardi* on page 414. In view of the fact that only one specimen of the Ontario representative of *Leucichthys nigripinnis* is preserved, it is not possible

[39] Figures for counts are given for all collected specimens. Proportions are given for specimens 225 millimeters or more in length in the case of *artedi* and for *hoyi* for those 200 millimeters or longer.

[40] These proportions are those most affected by growth, and as the *artedi* average considerably larger, the figures have no other value than to indicate that in general *artedi* has a somewhat smaller head and eye.

to state what distinctive features the race possessed. It is certain, however, that in point of absolute size attained it far exceeded *hoyi*, and the shape of the body, to judge from the specimen and from representatives of the species in other lakes, is more ovate in side view in *nigripinnis prognathus* and elliptical in *hoyi*.

GEOGRAPHICAL DISTRIBUTION

All my data on the occurrence of *hoyi* in Lake Ontario are given in Table 64 and are shown platted on a chart of that lake in Figure 7. For the most part they are gathered from the use of 2½ and 2¾ inch gill nets set by me from the various ports on the lake, but some observations on the species also have been made from 3-inch herring nets and 4¾-inch whitefish nets lifted from these ports. As specimens were found in the experimental nets out of every port from which they were set, and as the ports visited are widely scattered along the lake's shores, it is safe to conclude that *hoyi* occurs throughout the lake where suitable ecological conditions obtain.

BATHYMETRIC DISTRIBUTION

It has previously been stated that the only sources of data on the occurrence or distribution of any of the deep-water Leucichthys were the experimental nets referred to in the preceding paragraph. These nets were set for the most part only at such depths at which two or more species might be expected to occur, and no efforts were made to determine the depth range of any form. The records show small individuals ensnarled in the 4¾-inch whitefish nets off Bronte, Ontario, in 16 fathoms on June 30, 1921 (record 3), and gilled specimens in the 2½-inch nets off Wilson, N. Y., in 20 fathoms on July 21, 1921 (record 18). These are the shallowest sets in which any Leucichthys were observed by me in Lake Ontario. The deepest water explored by me was 70 to 75 fathoms, from which nets were lifted off Oswego, N. Y., on September 4, 1923 (record 10) and some *hoyi* were present in the catch of these nets. Records 7, 11, 13, and 17 show them to have occurred in nets lifted from depths of 60 to 65 fathoms out of Sandy Pond, Sodus Point, Charlotte, and Wilson, N. Y. It may be said, then, that the species ranges between 16 and 75 fathoms, but the figures do not set the limits of the zone of distribution.

RELATIVE ABUNDANCE

From many of the experimental sets made during the summers of 1921 and 1923 but few fish were taken, due, no doubt, in part, at least, to want of experience with conditions out of the various ports rather than to their actual rarity in the neighboring waters; but from most of those lifts that could be considered profitable from the fisherman's point of view the relative abundance of the species has been tabulated. On June 25, 1921, and on July 16, 1921, 5 miles north of Wilson, N. Y., in 50 fathoms, and on July 19, 1921, 6½ miles N. by W. ½ W. in 65 fathoms (records 15, 16, and 17), bloaters constituted 60, 90, and 25 per cent, respectively, of the catch. On July 4, 1921, 7 miles north of Braddock Point Light in 65 fathoms (record 13), 66 per cent of the fish taken were bloaters; and on July 12, 1921, 8½ miles NNW. of Sodus Point, N. Y., in 60 fathoms (record 11), they comprised 75 per cent of the lift. The species was not uncommon in lifts made on June 10 and 16,

1921, 20 miles S. by W. of Presque Isle Light, Ontario, in 40 to 50 fathoms (records 4 and 5), but the percentage was not ascertained. Few specimens were taken on November 23, 1917, off Winona, Ontario (record 1); on June 29, 1921, 13 miles E. ½ S. of Bronte, Ontario, in 40 to 50 fathoms (record 2); on June 23, 1921, and July 21, 1921, 3 miles north and 2 miles north of Wilson, N. Y., in 30 and 20 fathoms, respectively (records 14 and 18); on September 4, 1923, 8½ miles W. by N. ½ N. of Oswego, N. Y., in 70 to 75 fathoms (record 10); and on August 30, 1923, 14 miles west of Sandy Pond, N. Y., in 60 fathoms (record 7). The scarcity of fish in the 3-inch nets lifted on July 13, 1921, off Sodus Point, N. Y. (record 12); on September 1, 1923, off Nine-Mile Point, N. Y., in 30 fathoms (record 9); on July 11, 1921, 5 miles NNW. of Nine-Mile Point, N. Y., in 25 to 35 fathoms (record 8); and on August 24, 1923, 9 miles west of Sandy Pond, N. Y., in 25 to 28 fathoms (record 6), shows nothing conclusive about the abundance of the species, as the mesh of such nets is too large to take the species. Similarly, the rarity or absence of specimens from the 4½ and 4¾ inch whitefish nets is of no interest in this connection because the fish could only have become entangled accidentally in such netting.

Thus, the few observations on record show that the bloaters, though occurring between the depths of 16 and 75 fathoms, are most abundant, at least in summer, between the depths of 50 and 65 fathoms.

BREEDING HABITS

Except for a single example found among the spawning herring collected off Winona, Ontario, on November 23, 1917 (record 1), and one received from J. R. Dymond, of the University of Toronto, taken off Port Credit, Ontario, on March 28, 1926, no specimens of the species were seen between the dates of September 4 and June 10. None of the individuals collected as late as September showed any approach to sexual ripeness, and the fish collected in early June clearly had not spawned recently. The specimen taken on November 23, 1917, was a male with pearl organs and was therefore ready or nearly ready to spawn. The one taken on March 28, 1926, was a spent female. The spawning season, then, probably falls sometime between these dates.

LEUCICHTHYS ARTEDI LeSueur

THE BLUEBACK. THE CISCO. THE HERRING. (FIGS. 24, 25, AND 26)

Coregonus artedi LeSueur, 1818, pp. 231–232, "Lake Erie, and at Lewiston, upper Canada."
Argyrosomus artedi Evermann and Smith, 1896, pp. 305–309, pl. 21, Great Lakes.
Leucichthys artedi Jordan and Evermann, 1911, pp. 17–19, figs. 8 and 9, Lakes Huron, Erie, and Ontario; Dymond, 1926, p. 63, Pl. IV, Lake Nipigon.
Coregonus albus LeSueur, 1818, p. 232, Lake Erie (not of other authors).
Salmo (*Coregonus*) *harengus* Richardson, 1836, III, pp. 210–212, pl. 90, fig. 2, Georgian Bay.
Leucichthys harengus Jordan and Evermann, 1911, pp. 6–8, figs. 2 and 3, bays of Lakes Huron and Michigan.
Leucichthys harengus arcturus Jordan and Evermann, 1911, pp. 7–8, fig. 4, Lake Superior.
Coregonus clupeiformis De Kay, 1842, p. 248, Pl. LX, fig. 198, Lake Ontario; Agassiz, 1850, pp. 339–342, Lake Superior. (Not of Mitchill.)
Argyrosomus cisco Jordan, 1875a, pp. 135–138, Lake Tippecanoe, Ind.
Leucichthys cisco Jordan and Evermann, 1911, pp. 10–12, fig. 5, lakes of northern Indiana and southern Wisconsin.

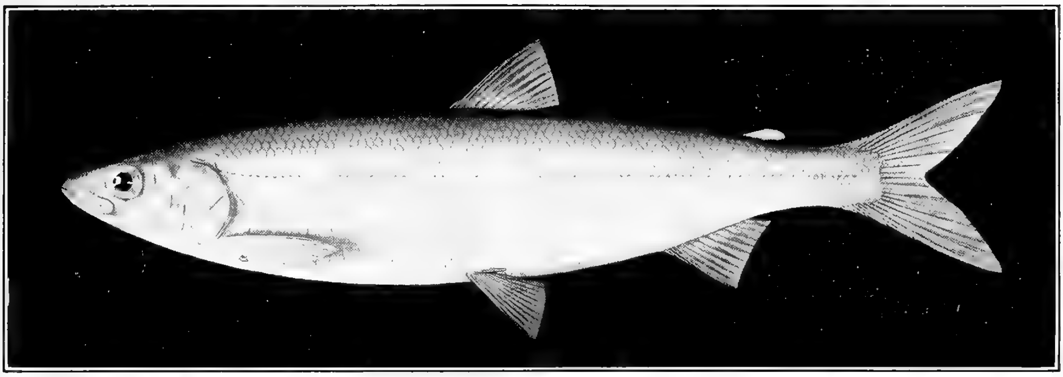

FIG. 24.—*Leucichthys artedi artedi* Le Sueur, the herring. Specimen, 244 millimeters long, taken in Lake Huron in Saginaw Bay in 4 fathoms on October 25, 1917

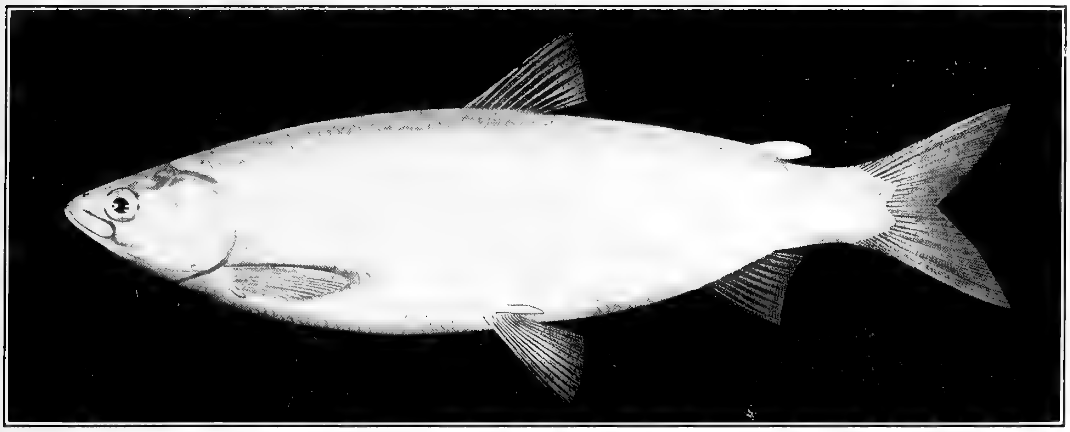

FIG. 25.—*Leucichthys artedi albus* Le Sueur, the Erie cisco. Male, 233 millimeters long, taken in Lake Erie off Sandusky, Ohio, on November 29, 1920

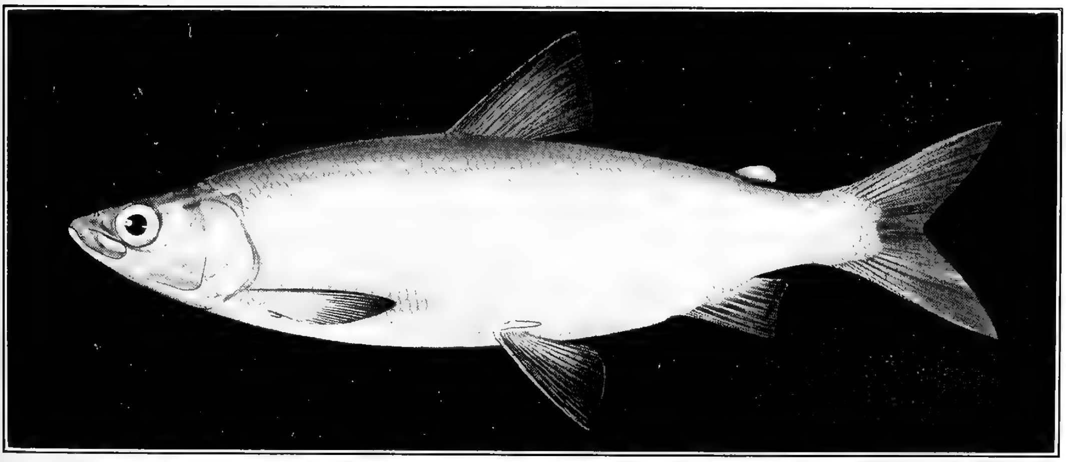

FIG. 26.—*Leucichthys artedi manitoulinus* Jordan and Evermann. Male, 250 millimeters long, taken in the North Channel of Lake Huron off Cutler, Ontario, on November 11, 1917

Leucichthys cisco huronius Jordan and Evermann, 1911, pp. 12–13, fig. 6, Pl. II, Lakes Michigan, Huron, and Erie.
Argyrosomus tullibee Evermann and Smith, 1896, pp. 320–322, pl. 28, Lake of the Woods (possibly also *Salmo* (*Coregonus*) *tullibee* of Richardson, 1836).
Leucichthys tullibee Jordan and Evermann, 1911, pp. 32–34, figs. 17 and 18, Winnipeg Basin.
Coregonus tullibee bisselli Bollman, 1889, p. 223, Rawson and Howard Lakes, Mich.
Argyrosomus tullibee bisselli Evermann and Smith, 1896, p. 322, lakes of southern Michigan.
Leucicthys artedi bisselli Jordan and Evermann, 1911, p. 20, fig. 10, lakes of southern Michigan.
Argyrosomus eriensis Jordan and Evermann, 1909, pp. 165–167, fig. 1, Lakes Erie and Huron.
Leucichthys eriensis Jordan and Evermann, 1911, pp. 20–22, fig. 11, Lakes Erie and Huron.
Argyrosomus huronius Jordan and Evermann, 1909, pp. 167–169, fig. 2, Lakes Erie and Huron.
Leucichthys manitoulinus Jordan and Evermann, 1911, pp. 31–32, fig. 16, North Channel of Lake Huron.
Leucichthys ontariensis Jordan and Evermann, 1911, pp. 13–14, fig. 7, Lake Ontario.
Leucichthys supernas Jordan and Evermann, 1911, pp. 22–23, fig. 12, Lake Superior.
Leucichthys macropterus Bean, 1916, pp. 25–26, Lake Erie.

The type specimen is not extant. The species was described as *Coregonus artedi*, the herring salmon, from "Lake Erie and Lewiston, upper Canada," by LeSueur in the May, 1818, number of the Journal of the Academy of Natural Sciences of Philadelphia. A second species was described by LeSueur in the same publication under the name *Coregonus albus*, "Lake Erie whitefish," but this form was distinguished from *artedi* in no other characters than in being less fusiform, deeper bodied, in having the back elevated from the nape to the dorsal fin, and "the proportions much stronger in body, fins, and scales"; and though a figure was given of what may be taken for a herring, apparently drawn from memory, there is nothing about this figure to indicate that LeSueur had the true whitefish in mind. No specimens on which were based the descriptions of either species are known to exist, and the practice of ichthyologists has been to attach the name *artedi* to the Lake Erie herring and to call the Lake Erie whitefish *albus*. This procedure does not take into consideration the fact that Lewiston is on the Niagara River below the falls and that any herring taken from that vicinity probably would not be the common Lake Erie type, and lets the fact that LeSueur called his *albus* the "whitefish" outweigh the considerations of his having failed to point out in his description or to indicate in his drawing the striking difference in the position of the mouth of the whitefish as compared with that of the herring. If, on the other hand, we assume that LeSueur got a Lake Ontario herring at Lewiston and then a herring from Lake Erie (which, by the way, was obtained much more easily in the early days than the whitefish), his descriptions are applicable, especially if by "stronger proportions" (by which he distinguishes *albus* from *artedi*) he meant greater depth of body, longer fins, and larger scales. According to this view, then, the Lake Ontario shallow-water herring, which also occurs sparingly in Lake Erie, is the type race of *artedi*, and the name *albus* may be used for the common Lake Erie race and for the deep-water race that is known to exist in the western waters of Lake Ontario and elsewhere.

The lake herring is the most widely distributed and the most variable species of Leucichthys in the Great Lakes Basin. The range of variations lies between the slim terete herring of Lake Superior (an extreme of the *artedi* type) and the deep,

compressed herring of Erie, the *albus* type, or the still more extreme tullibee [41] of the western Canadian lakes represented by the dark-colored *manitoulinus* in the North Channel of Lake Huron. While a school in a given locality usually presents a uniform appearance, specimens that show an approach to the extremes often may be found in it.

In all the Great Lakes and Lake Nipigon and in many of the deeper inland glacial lakes of the basin the species *Leucichthys artedi* occurs, and it is represented by races that resemble more or less closely one of these types. This variability in external appearance has confused systematists, and in the absence of information on their natural history many of these races have been described as distinct species. In the latest revision of the coregonids of the Great Lakes, Jordan and Evermann (1911) accredit seven such species and one subspecies to the Great Lakes. They are listed here under the synonomy of *L. artedi*, and the reasons therefor are given under the various systematic accounts of that species. Two subspecies of *artedi* are recognized—*albus*, typically of Lake Erie but occurring also in Lakes Superior and Ontario, and *manitoulinus* of the North Channel of Lake Huron. Typical *artedi* are found in all the lakes.

Leucichthys artedi artedi and artedi albus of Lake Erie

The lake herring, while probably the most important commercial species in Lake Erie, does not attain great size as a rule. The specimens taken in the 3-inch gill netting, which is legal now everywhere and is employed most generally in their capture, do not average a pound in weight regularly. However, specimens weighing 1½ pounds are not rare, expecially in the western sector, and individuals weighing 5 or 6 pounds have been reported. The shape of the body is usually decidedly fusiform, elongate, and subterete in specimens of little depth and shortened and more or less compressed in deeper individuals. In side view the shape usually is decidedly elliptical. The dorsal profile in that case rises gradually and evenly from the tip of the premaxillaries to the insertion of the dorsal and curves gently from the dorsal to the caudal peduncle. The ventral profile is like the dorsal, except that from the tip of the mandible to the ventrals and from the ventrals to the caudal peduncle the lines are more curved than the opposite dorsal lines. Often in the case of specimens from the western waters over 1 pound in weight, and sometimes in the case of deep specimens not more than ½ pound in weight, there is a sudden rise from the occiput for one-fourth to one-third the distance to the dorsal insertion, so that there is more or less of a hump in the occipital region of such individuals. In the western sector the herring apparently grow larger (superficial examination of the scales indicates that they also grow faster than those in the deeper waters of the east), and jumbos (large individuals) are much more frequent than elsewhere in the lake. Jordan and Evermann (1909), influenced by these characters, recognized this form as a distinct species under the name *eriensis*.

Rate of growth and body shape have been found to be so variable in the case of the lake herring, and as this form differs in no way from other herrings in habit,

[41] Probably *Salmo* (*Coregonus*) *tullibee* of Richardson (1836), though it can not be stated so positively until material is known for the type locality. Until this is available, the name may stand for the tullibee of Lake of the Woods and Lake Winnipeg, which I consider members of the *Leucichthys artedi* species group.

and as all, including the long, slender, blue-backed type (the *cisco huronius* of Jordan and Evermann), may be taken in the same spawning school, the various types can not be considered more than races. The satisfactory differentiation of these races still remains to be made. The depth of the body is very variable and ranges between the limits of (2.8) 3.3–3.7 (4.8),[42] the figures being highest in the "blueback" or typical *artedi*. The width of the body also is variable. In the *albus* form it comprises about 49 or 50 per cent of the depth but in typical *artedi* may be more than 60 per cent. The head is more or less compressed, broadly triangular in side view, and is contained (4.1) 4.3–4.7 (5.2) times in the total length. Its dorsal profile is more or less convex. The premaxillaries are always pigmented and are very short, scarely longer than wide; they usually make an angle of 45° to 55° with the horizontal axis of the head. The snout is obtuse in side view, short, sometimes equal to or shorter than the eye, never much longer, and is contained (3.6) 3.8–4 (4.5) times in the head length. The eye is relatively small, is usually situated in the second quarter of the head length (though often in the smallest specimens encroaching on the third), and is contained (3.8) 4.2–4.5 (4.9) times in the head length. The maxillary is always pigmented except on its distal end, is short, and is contained (2.5) 2.7–2.9 (3.3) times in the head. The mandible is also always pigmented, is rather weak, and is usually equal to or shorter than the upper jaw, though often somewhat longer. The gill rakers on the first branchial arch number (15) 16–18 (20) + (26) 28–31 (33) = (41) 44–48 (53).[43] The scales in the lateral line number (64) 71–81 (89),[44] their number directly influencing the size of the body scales. Scale rows[45] around the body just in front of the dorsal and ventrals number (38) 40–42 (46), just in front of the adipose and anus (31) 32–34 (36), around the caudal peduncle at its commencement (23) 24–25 (27). The paired fins are short. The pectorals are contained (1.6) 1.9–2.1 (2.5) times in the distance from their insertion to that of the ventrals, and the ventrals are contained (1.4) 1.6–1.8 (2.1) times in the distance from their insertion to that of the anal. There are (8) 9–11[45] dorsal rays, 10–12 (13)[45] anal rays, (10) 11 (12)[45] ventral rays, and (14) 15-16 (18)[45] pectoral rays.

The general appearance in life is silvery, with a faint pinkish to purplish iridescence on the sides. The underlying color on the back is blue green to pea green of moderate intensity, except in the case of the "blueback," which is usually deep blue green. This color extends on the sides about halfway to the lateral line and then pales gradually to the colorless belly, becoming more bluish below the lateral line. The cranial and preorbital patches are present and vary in color like the back. The effect of the general color is deepened by the uniform but inconspicuous fine pigmentation, which covers the back to about halfway to the lateral line. On the sides the pigment grows less and disappears entirely below the lateral line about halfway to the belly. The pigment dots on the cranium, in the preorbital area, and on the maxillary are abundant but so fine as to cloud only slightly the whiteness of the cartilage; but in the prenarial region, on the premaxillaries, and on the mandible

[42] These and other figures, unless otherwise designated, are based on an examination of 163 specimens ranging in length from 225 to 402 millimeters. Values for both forms are grouped together as many specimens occur that are intermediate. The higher values for L/D, Pv/P, Av/V, L/H, and for scales and scale rows are from typical *artedi*.

[43] Three hundred and thirteen specimens.

[44] Seven hundred and fifty specimens.

[45] Forty specimens.

they are more concentrated and give a darker hue to these areas. The cheeks and iris are silvery, with faint iridescence. The dorsal and caudal fins are sprinkled with pigment and the distal ends are darker, but not conspicuously so, except sometimes on the shortest rays of the caudal. The abdominal fins are whitish transparent without conspicuous pigmentation, though the anal and pectorals often have a sprinkling of pigment.

All color fades in alcohol and leaves the details of pigmentation more obvious. The dorsal and caudal show a more conspicuous dark band on their tip, and the back of the "blueback" remains decidedly darker.

Pearl organs are present to some extent on all males in the breeding season and probably on all females. They are developed best in the males and are indicated only faintly in females. Their development is not different in general from that described for the chub (p. 350), except that the irregular pearls on each scale in the predorsal and preventral areas possibly may be more numerous in this form.

VARIATIONS

Racial variations.—In Lake Erie, Jordan and Evermann (1911) found three species of lake herring, which were named by them *Leucichthys cisco huronius*, *L. artedi*, and *L. eriensis*. In addition, Bean (1916) described a form *L. macropterus* from a single specimen obtained at Erie, Pa. No other individuals like it have been collected and none have been seen by any of the numerous fishermen interviewed by me on Lake Erie, so that it may be assumed that Bean had a monstrosity. Clemens (1922), in following Jordan and Evermann, distinguished the three species reported by them for the lake and two others, *L. harengus* and *L. prognathus*. The form *harengus* is distinguished very unsatisfactorily from *cisco huronius* by Jordan and Evermann themselves, and *L. prognathus* is a deep-water form that is taken seldom in any of the other Great Lakes in less than 60 fathoms and therefore is not likely to be found inhabiting Erie, with a maximum recorded depth of about 30. Doctor Clemens, however, expresses his uncertainty about the applicability of the names *harengus* and *prognathus* to his forms, and the consideration of them as belonging to Erie may be dismissed for the time being.

The fishermen of Lake Erie find no differences in the Leucichthys of the lake except that those of the eastern end, where the water is deepest and where the population is densest, average smaller and those on the shallow western flat, where herring are few, more often attain exceptional size (1 pound or more). All are considered herring and, so far as the fishermen know, all spawn together. From an examination of several thousand specimens from the eastern end of the lake taken out of Dunkirk and Barcelona, N. Y., Erie, Pa., and Port Dover, Ontario, and from the western end of the lake taken out of Sandusky, Ohio, Monroe, Mich., and Merlin, Erieau, Ridgetown, and Port Stanley, Ontario, it is possible to understand the conclusions at which the systematists and fishermen have arrived. In Lake Erie there is a slim terete form, typical *artedi* (*cisco huronius* of the writers cited), that is distinguishable from the much more numerous *albus* form (*artedi* of the writers cited) by its shallower, less compressed body, shorter paired fins, smaller adipose fin, more numerous scales and scale rows, and darker color of the back. Such of these characters as can be expressed numerically are compared for the two forms in Table 67.

In all respects these slim terete individuals resemble the shoal herring of Lake Ontario and the upper lakes, and as they are relatively rare and occur but very rarely in the eastern part of the lake, it may be that they are immigrants from the upper waters through the Detroit River, or they may be only rare examples of the extreme development possible to the species. Certainly they spawn along with the typical Erie form, as spawning specimens of both sexes were found in a catch of spawning herring at Sandusky, Ohio, in November, 1920, and unless there is Mendelian segregation, their characters would be unrecognizable in the second generation.

The other herring at the western end of the lake are but slightly differentiated from those of the east. The most important difference is the greater average size of the catch. The gill nets used throughout the lake are of the same mesh, and while specimens weighing over 1 pound are rare, relatively, in the east, they may at times at least be common in the west. These fish of greater size—jumbo herring—are the *eriensis* of Jordan and Evermann and are found by Clemens to grow more rapidly than the *artedi* (of his paper) of the deep water to the east. Except that larger individuals are sometimes somewhat humped at the nape (see p. 478) and that the mandible is less often longer than the upper jaw in the western specimens,[46] there are no constant differences. There are indications that the eastern form may have somewhat more scales in the lateral line and somewhat different proportions, at least as concerns head, eye, maxillary, paired fins, and depth; but the two groups compared were of individuals of different average size, and those proportions that appear to be different are precisely those that are influenced by growth. Experience indicates, furthermore, that the course of a curve like that which might be platted from the data given for lateral-line scales may be altered in either direction to the extent in which the two groups differ from one another by the addition of more data obtained from specimens from another catch. Both jumbos and other herring are found in the same spawning school.

The *eriensis* of Jordan and Evermann, which is characterized chiefly by its large size, according to these authors appeared in the catches but a few years before their discovery of it. For many years before Lake Erie had been fished intensively, and no species could have escaped discovery, as these writers seem to imply. On the other hand, the phenomenon of increased size of individuals in a depleted area is not new and has been demonstrated conspicuously in the case of the Lake Erie herring since. The herring were depleted first in the west and were produced more abundantly then toward the east. The jumbos, then, were caught farther to the east, and it is believed by most of the fishermen on the eastern Canadian shore that the fish in these localities have been larger latterly, on the average, than formerly. W. D. Bates, of Ridgetown, Ontario, says that until about 1898 the herring occurred in his pounds in enormous schools and were so small and thin that they were of little value. A fish 1 pound in weight was rare. Now his catch of this species is very light, but individuals frequently weigh 2 to 3 pounds.

The occurrence of relatively large numbers of individuals with long mandibles in the deep water of the east end of the lake confused Clemens and caused him to

[46] In eastern specimens the mandible is shorter than the upper jaw in 241 specimens, equal in 256, and longer in 211; figures for western fish are 42, 35, and 15, respectively.

segregate these individuals under the name *prognathus*. However, he found the rate of growth of the long-jawed specimens to be like that of their associates. On October 25, 1920, I examined several hundred specimens from a lift of some thousands of pounds of herring taken off Port Dover, Ontario (the source of Clemens's specimens), and found them to be typical *albus;* so there seems to be no reason to believe that any other Leucichthys, least of all the deep-water *prognathus*, occurs in Lake Erie. The tendency of individuals of a shallow-water species living in deep water to acquire a longer mandible is illustrated by *L. hoyi*, also. (See p. 460.)

Size variations.—Only a few specimens are available for a comparison of changes with growth. In Tables 8 to 11 are shown the relative proportions of large and small specimens, and in Table 67, 10 specimens under 200 millimeters are compared extensively with 3 groups of 10 each of specimens larger than 200 millimeters. Only between the large and small individuals taken at the eastern end of the lake can comparisons be drawn satisfactorily, as these presumably are related genetically. In the case of these the data indicate (as was to be expected) that the head and eye are relatively larger in the small individuals. The paired fins also appear to be longer and the depth less.

Specimens under 17 centimeters in length have been taken only in the eastern waters and have been found to be sexually immature. Larger individuals usually have been mature. In western waters no mature specimens have been seen smaller than 23 centimeters.

COMPARISONS

Leucichthys artedi and *Coregonus clupeaformis* are the only coregonids known from Lake Erie. The generic distinctions are quite evident, and the species are not confusable.

GEOGRAPHICAL DISTRIBUTION

Herring occur in schools, and these formerly occurred not only out of every port on the lake but in almost every situation in it. Almost since the beginning of fishing operations the herring has been an important factor in the commercial fisheries, and for many years it has been their mainstay, particularly in the eastern waters. In the west, on the flat westward from Sandusky, the schools have been so depleted that herring fishing has been virtually abandoned in this area for 25 years. The middle grounds (that is, the 100-mile stretch between Point Pelee on the west and Long Point on the east, which has a maximum depth of 14 fathoms) until about 1920 produced several million pounds of herring annually. Since 1925 the deep hole to the east of Long Point also has been depleted, and the herring, once present in supposedly inexhaustible quantities, is commercially near extinction. In Table 66 are given data for the specimens that I have collected.

METHODS OF CAPTURE

Gill nets are used most widely for taking the species. Until recently, nets of meshes as small as 2¾ inches were allowed by some States on the ground that the herring in the eastern waters were smaller than those elsewhere, but the legal net is now everywhere of 3-inch mesh. The gill nets are commonly of exceptional depth

(often as much as 25 feet deep) and in that case are called bull nets. There is a growing sentiment against their use, and most of the States already have enacted laws limiting the depth of gill nets. Whether bull nets or narrower nets are used, it has been the universal practice for more than 10 years to float them at certain seasons at least. They are buoyed off the bottom by the use of air cans and may be set in any stratum, the distance off the bottom varying with the ascertained location of the schools of fish. When the fish are spawning in the fall the nets usually are sunk to the bottom. Westward of Port Stanley to Point Pelee, on the Canadian shore only, some herring are produced by pound nets. Some are taken in pound and crib nets elsewhere on the lake, but the quantity is relatively small.

It appears, thus, that originally herring were so numerous that they occupied every situation in the lake and could be captured at any season. The pound nets took them on shore often throughout the season but usually most abundantly during June and July. In the last decades they have been obtainable in gill nets in certain sections of the lake in the spring, but the best fishing outside the spawning run was to be had by floating the nets in the summer. In the fall when the fish collected to spawn they were taken more or less abundantly over most of the lake, especially the eastern half.

SEASONAL MOVEMENTS

Originally herring were so abundant that in parts of the lake, at least, they could be taken in commercial quantities at any time of the year by nets set on the bottom. In later years the schools became decimated, some of them even exterminated, and the fish could be captured only on the bottom at certain seasons and out of certain ports. The time finally came when the supply of the fish on the bottom became so uncertain as to make necessary the floating of nets off the bottom in order to supply the demand. Out of the practice of floating developed the bull net, a net four or five times deeper than the gill net formerly in use. This apparatus was floated also, and on account of the shallowness of the lake and the immensity of the netting employed the remaining schools were subject to capture virtually at the pleasure of the producers.

Data from the pound nets.—At present very few herring are taken in pounds anywhere on the lake. Occasionally a producer may make a total catch of a few thousand pounds in these nets, usually in June or November, but the species is no longer counted on as a mainstay of these fisheries. The testimony of the pound netters of the north shore indicates that June and July were usually the best months, with August usually poorest; but an examination of the records of the pound nets of W. D. Bates, at Ridgetown, and A. Crewe, at Merlin, shows that while the lifts usually were heaviest during these months, there have been years when good lifts of herring were made in every month from April to December. The presence of the fish on the shoals during these summers probably would be found to be due to unusually low summer temperatures.

Data from the gill nets.—In late years nets have been set for herring in the spring, when the fishing season opened on March 15 in the area between Port Stanley, Ontario, and Ashtabula, Ohio. The fish scattered about the 1st of June and reappeared about July 1 farther west, between Erieau, Ontario, and Cleveland, Ohio, and east in the deep water off Erie, Pa. The schools began to thin out toward the west on the central flat as summer advanced and to appear farther east, so that by

September 1 herring fishing began out of Dunkirk, N. Y., the extreme eastern port. Out of most of the ports, except those on the east hole, herring fishing was light during the latter part of September and October, but in November again heavy catches were made from Pelee Island on the west to the east end of the lake, with the greatest production in the east. In the summer months bull nets were used as a rule, floated at various depths according as the fish were high or low, though in the early days the fish are said to have been most abundant on the bottom in July and August. At other times narrow nets were fished on the bottom.

BREEDING HABITS

The herring formerly spawned out of virtually every port on the lake. The spawning grounds most frequented in late years were situated from 4 to 10 miles or more offshore, in depths, in the east end of the lake, of 15 to 25 fathoms, and in the west of about 10 fathoms. The bottom in these areas usually is clay, though there are stretches of gravel. A few, of course, also spawned in shallower water.

The time of spawning, according to all the fishermen, fell in late November to early December, being earlier or later, according to the season. Those in the east usually spawned latest. According to the records of A. Crewe, of Ridgetown, Ontario, the fish taken in his pounds were through spawning on November 26, 1917. As late as December 6 in 1920 they were just beginning to spawn. On November 24, 1924, I found the fish in these nets just beginning to ripen.

VALUE AS FOOD

The Erie herring is superior in quality to the herring of any of the other lakes, except possibly those from the deep water of western Lake Ontario. They are very much in demand as fresh fish, and the large examples frequently are sold as whitefish. They have also competed strongly with the chubs of the deeper lakes in the smoked-fish trade. While they are not quite so rich in oil as the latter, they are larger and more uniform in size. Until the collapse of the herring fisheries in 1925, there was no market for chubs in New York City.

Leucichthys artedi artedi of Lake Michigan

The Michigan form resembles the slender blueback of Lake Erie (typical *artedi*) rather than the common *albus*. A comparison of the principal taxonomic characters of the two forms follows:

Gill rakers on the first branchial arch:
- Erie, *albus*, (41) 44–48 (53).[47]
  - *artedi*, (44) 46–50 (51).[48]
- Michigan, (41) 46–50 (55).[49]

Lateral-line scales:
- Erie, *albus*, (64) 71–81 (89).
  - *artedi*, 76–86.
- Michigan, (68) 77–87 (94).[49]

L/H:
- Erie, *albus*, (4.1) 4.4–4.7 (5.2).
  - *artedi*, 4.5–5 (5.2).
- Michigan, (4.1) 4.3–4.5 (5).

H/E:
- Erie, *albus*, (3.8) 4.2–4.5 (4.9).
  - *artedi*, 4.1–4.5 (4.7).
- Michigan, (3.6) 4–4.2 (4.7).

[47] Figures of Lake Erie *albus* for proportions are given for 148 specimens ranging in length from 225 to 402 millimeters. Those for gill rakers are given for 298 specimens; for lateral-line scales, for 735.

[48] Figures for Lake Erie *artedi* are given for 15 specimens ranging in length from 229 to 341 millimeters.

[49] Figures for Lake Michigan so designated are based on an examination of some 391 specimens ranging in length from 127 to 367 millimeters. Those figures dealing with proportions are based on an examination of 148 individuals ranging in length from 225 to 367 millimeters.

H/M:
Erie, *albus*, (2.5) 2.7–2.9 (3.3).
artedi, 2.6–3 (3.3).
Michigan, (2.5) 2.7–3 (3.3).
H/S:
Erie, *albus*, (3.6) 3.8–4 (4.5).
artedi, 3.6–4 (4.2).
Michigan, (3.3) 3.7–4 (4.4).
Pv/P:
Erie, *albus*, (1.6) 1.9–2.1 (2.5).
artedi, 2.1–2.5.
Michigan, (1.6) 1.9–2.2 (2.6).
Av/V:
Erie, *albus*, (1.4) 1.6–1.8 (2.1).
artedi, 1.7–2 (2.1).
Michigan, (1.4) 1.6–1.8 (2.3).
L/D:
Erie, *albus*, (2.8) 3.3–3.7 (4.3).
artedi, 3.7–4.8.
Michigan, (3.6) 4–4.9 (5.3).

The figures show that the Michigan form differs from that of Erie *albus* most strikingly in having less depth of body. They indicate also that the former has, on the average, more gill rakers on the first branchial arch, more lateral-line scales, and a slightly larger head and eye. The mandible has been found to be longer than the upper jaw in only 8 per cent of the specimens over 225 millimeters in length and usually is equal or shorter. There are very few specimens of the Erie blueback or *artedi* form for comparison, but the Michigan race seems to be very like it. The only difference seems to be that the Michigan specimens have a larger head and eye and longer paired fins, but these differences may be due to the fact that the Michigan specimens average much smaller. The Michigan race seems, then, to merit the designation *artedi*.

The color in life is about like that of the blueback of Lake Erie. There is, as a rule, more pigmentation on Michigan specimens, particularly on the back and head. The ventrals frequently show some pigment, and the anal usually is dotted with black.

Pearl organs are developed, at least by the males. Specimens taken in Green Bay on November 11, 1920, showed pearls that differ in their development in no material way from that described for the typical form.

VARIATIONS

Racial variations.—There is a wide variation in all characters exhibited even by individuals from the same school (see Table 69), but it is likely that, if enough specimens were collected, at least the schools from certain areas of the lake would show tendencies to vary in a definite direction. Very few unusual specimens were seen from any part of the lake, and there is, therefore, no reason to believe that any races, sharply differentiated by external characters, such as *manitoulinus* in Lake Huron, occur in Lake Michigan. The fisherman, however, are of the opinion that two distinct races inhabit Green Bay. The one they catch in the summer at depths of 10 to 20 fathoms in gill nets, and the other is caught in fall on the shores in gill nets and pounds. The first mentioned are known as bluefins, in contradistinction to the blue-backed herring, which they are accustomed to take in shallower water. Except that the deep-water fish are paler and perhaps a trifle fatter and of deeper body, characteristics that might easily be induced by the environment, there are no apparent differences, and an examination of some 35 specimens of each supposed variety shows that the two groups do not differ in the systematic characters that ordinarily are variable

in the species. A study of the rate of growth of specimens from both situations would, of course, also aid in determining their racial identity. In Table 69 are compared extensively 10 specimens from Green Bay—5 from the shore and 5 from the deepest water—and 9 taken at various ports on the lake.

Size variations.—Below are given, for the characters that vary most with growth, values for large fish (225 millimeters and over) and small ones (under 225 millimeters). More detailed figures are shown for some of these characters in Tables 8 to 11. Ten specimens under 200 millimeters are compared extensively with larger fish in Table 69, also.

L/H:
- Large fish, (4.1) 4.3–4.5 (5).
- Small fish, (4) 4.2–4.5 (4.6).

H/E:
- Large fish, (3.6) 4–4.2 (4.7).
- Small fish, (3.5) 3.7–4 (4.3).

H/M:
- Large fish, (2.5) 2.7–3 (3.3).
- Small fish, (2.4) 2.7–3 (3.1).

H/S:
- Large fish, (3.3) 3.7–4 (4.4).
- Small fish, (3.4) 3.6–3.9 (4.1).

Pv/P:
- Large fish, (1.6) 1.9–2.2 (2.6).
- Small fish, (1.6) 1.8–2.1 (2.5).

Av/V:
- Large fish, (1.4) 1.6–1.8 (2.3).
- Small fish, (1.3) 1.5–1.7 (2).

L/D:
- Large fish, (3.6) 4–4.9 (5.3).
- Small fish, (4.1) 4.4–5 (5.8).

Jaw:
- Large fish, equal or shorter, 92 per cent.
- Small fish, equal or shorter, 65 per cent.

It appears from these data that the eye and paired fins decrease proportionally in size with growth, the depth of the body becomes greater, and the jaw tends to become shorter. The head and snout do not change markedly in relative size, but they also appear to be a trifle shorter, relatively, in adults.

A few individuals of both sexes have been found sexually mature at 165 millimeters, but usually those smaller than 180 millimeters show no development of the sex glands.

COMPARISONS

Artedi is usually easily distinguishable from any of the deep-water Leucichthys. Its flesh is much less fat that that of any of these, and it is usually distinguishable from them by other characters also. Small individuals, however, sometimes closely resemble *hoyi*. A discussion of the differences between *artedi* and *hoyi* is found on page 452. The differences between *artedi* and *johannæ, alpenæ, zenithicus, reighardi, nigripinnis*, and *kiyi*, are given on pages 353, 366, 391, 403, 419, and 436.

GEOGRAPHICAL DISTRIBUTION

The herring of Lake Michigan occur in schools and are taken extensively at some seasons of the year out of virtually every port on the lake. The long stretches of sandy shore seem favorable for this species, and herring are abundant enough therefore in most places to make their capture profitable. Green Bay is the most productive area. I have collected specimens from virtually every port visited. The data for these are given in Table 68 and are platted on the lake chart in Figure 4.

METHODS OF CAPTURE

Most of the herring are taken in gill nets and pound nets with small-meshed pots. Gill nets are in use in Green Bay in the summer when the fish are offshore, in the

winter through the ice, and also to some extent in the fall. They are used in many localities also where the run of herring is not heavy enough to warrant the placing of pounds. The size of the mesh of gill nets employed varies from 2⅛ to 2¾ inches, depending on the various State laws. Pound nets for herring are commonest in the Green Bay district, but a few are employed at various points along the shore line of every State bordering on the lake. In Green Bay of late years some have been operated in the winter.

SEASONAL MOVEMENTS

The herring schools are ashore both in spring and fall and in many places they probably stay near shore all winter. The schools are more or less pelagic, and their movements probably are influenced materially by the food supply, but it is interesting that they do not approach the shore when the water there is warmest.

Data on occurrence in the herring nets in spring and fall.—In Green Bay, according to R. F. Kleinke, the herring are found near shore as soon as the pound nets can be put in in April or May. After June they disappear from the shores but return in some numbers about the middle of September. They increase in abundance until the spawning time during November, and then they leave until the ice forms, when they are taken frequently under the ice. They are said to move erratically in the winter and frequently are absent from the netting grounds entirely for some days at a time. The deep-water form, which is taken most commonly in summer in the bay at depths of 10 to 18 fathoms, is said by some fishermen to be found there all the year round except when it comes ashore in November to spawn, while others maintain that it occurs in these depths only during the summer months. It is probable that all the fishermen have a basis for their statements, but that the first group catches chubs among the herring at certain seasons and are not able to distinguish them. It is certain that the catches examined by me on August 16, 1920, made in 11 to 16 fathoms between Green Island and Little Sturgeon (records 1 and 2), consisted exclusively of herring; and as the lake's heat budget was near its maximum at this season, it is clear that the fish found tolerable conditions at that depth in summer. Reasoning from analogy on the basis of the behavior of herrings elsewhere and of other coregonids, it is to be expected that they would move into shallower water as the waters cooled. At Port Washington, Wis., Delos Smith says the herring are found in the pound nets in 20 to 60 feet as soon as they can be set in April. The runs are heaviest in May, and by July 1 they are over. Occasionally a school comes into the nets in summer, but there is no herring fishing of consequence until after September 15. During October and early November the runs are at their height. The fall run, Mr. Smith states, consists of larger fish. At Milwaukee, Wis., George and Fred Tilly find the herring in 8 fathoms during April and May in gill nets, and again in October and November. At other times they pursue more valuable fish. Record 15 was made from the net of the Tilly brothers and shows that herring were caught in 10 to 15 fathoms off Milwaukee on March 24, 1919. F. C. Kimball, of Michigan City, Ind., says that the herring are found as soon as the pound nets are put in in April at depths of 18 to 30 feet on sand bottom. There are good lifts until early May. After that the schools are erratic in their movements and come ashore only when favorable currents have cooled the shore waters. In October the lifts are

again heavy, and the fish are caught until the nets are blown out. On March 2, 1921, small herring were taken occasionally among the bloats by the 1½-inch gill nets set 14 miles NNW. in 26 fathoms and in the 2½-inch nets lifted on March 4, 1921, 15 miles NW. by N. ½ N. in 28 fathoms (records 22 and 23). Numbers of herring have not been recorded by me at greater depths in Lake Michigan; the presence of the fish at such depths may have been due to stormy conditions, which usually obtain in March. In that case the records, in all probability, could be duplicated out of any port where no ice is formed in winter. The pound nets are set at Grand Haven, Mich., about April 10, according to Mr. Mieras and Johannes Fischer, in 16 to 20 feet on sand. Herring are present at once and continue on the grounds during May and June. None are taken thereafter, because the pounds are pulled by September. However, Mr. Mieras does set gill nets for the white perch during September and October at depths of 6 to 15 fathoms, but he gets very few herring in them, although the mesh is suitable for their capture. At Manistee, Mich., the spring behavior of the herring, as reported by Peter and Hans Petersen, is like that recorded for Grand Haven. The Petersens do not fish herring in the fall. The accounts given for Northport, Mich., by Hans Anderson and Carl Schrader and for Traverse City, Mich., by Will Hopkins, Otto and Doner West, and Floyd Stiles are virtually the same as those recorded for Port Washington. The Northport fishermen and Mr. Hopkins say they have known the herring to remain along the shores under the ice in the bay. At Seul Choix, Mich., they appear to stay a little later than at any of the places so far mentioned, and Alex Goudreau says they are taken frequently in the pounds through July. Seul Choix is farther north than any of these places, and the water conditions may be slightly different.

Data on summer occurrence.—Except in Green Bay (and here only since about 1910), no herring are taken when they leave the shoals in spring. In Green Bay they certainly occur abundantly at depths of 11 to 16 fathoms in August. They were being taken in commercial quantities by gill netters between Green Island and Little Sturgeon on August 16, 1920, at these depths (records 1 and 2). A lift made on August 18, 1920, 4 miles west of Boyer Bluff near the outlet of Green Bay, in 18 to 24 fathoms (record 5), took about half herring and half *hoyi*, and most of the former were at the 18-fathom end of the gang. Specimens were collected from a similar gang lifted on August 18, 1920, 7 miles NNW. of Boyer Bluff in 11 fathoms (record 6), but it is not known how abundant herring were in this lift. The only other summer records that indicate that herring may have been abundant on the grounds in question were made off the northwest end of St. Martin's Island at the mouth of Green Bay on August 19, 1920, in 14 fathoms on rock bottom (record 10), and on August 11, 1920, 13 miles SE. ½ E. of Manistique, Mich., in 20 fathoms on sand (record 41). On both occasions herring (mostly individuals under 200 millimeters in length) were caught rather commonly in the 4½-inch trout nets by becoming ensnarled in their meshes. A few also were caught in the same manner on August 18 and 19, 1920, 5 miles west and 3 miles WNW. of Boyer Bluff in 20 to 24 fathoms on rock bottom (records 7 and 8). Other data collected in summer show a few stragglers in the pound nets in Grand Traverse Bay (Barrow's Harbor) on July 19 and 26, 1923 (records 38, 39, and 40), in 5 fathoms, a few in the 1½-inch gill nets set in 4 to 16 fathoms off Lee's Point on July 25, 1923 (records 34 and 36), and a single specimen seined

on the shore of Lee's Point in the bay on July 25 (record 35). On July 21 and 23, 1923, 1½-inch gill nets set in 8 to 12 fathoms and 15 to 25 fathoms offshore 1½ miles south of Otter Creek in Platte Bay took 1 and 12 individuals, respectively (records 26 and 27). On the South Manitou Island off the light on July 30, 1923, a few stragglers were taken in seines, 1½-inch gill nets, and pound nets in 1 to 5 fathoms of water (record 28). Stray specimens also were collected off Manistee, Mich., on August 27, 1920, in pound nets in 4 fathoms (record 25), and off Seul Choix Point on August 20, 1920, at about the same depth (record 42). Records 17 and 18 show a few herring among the chubs taken on September 24, 1920, 9 miles NNE. of Milwaukee, Wis., at a depth of 22 to 25 fathoms, and on November 15, 1920, 5 miles E. by S. ½ S. in 12 fathoms. There are numerous records that show an occasional fish of this species being taken in the chub nets lifted from depths of 30 to 90 fathoms (vide records 9, 11, 12, 13, 16, 19, 21, 23, 29, and 31 for Washington Harbor, Sturgeon Bay, Algoma, Port Washington, Milwaukee, Michigan City, and Northport); but these fish may have been caught while the net was being set from schools traversing the upper strata. The few small examples taken in 1½-inch nets on June 23, 1920, off Northport Point and on July 18, 1923, in Grand Traverse Bay in 28 to 40 fathoms (records 30 and 37) possibly were caught in the same way.

On the other hand, it is not at all impossible or improbable that specimens normally stray to great depths. It has been shown that many of the Leucichthys have a very broad depth range, and it is known that other shoal-loving fish may occur in very deep water. On July 2, 1923, in Lake Huron, 20 miles E. by N. of the Alpena can buoy, a gang of chub nets brought up a sauger (*Stizostedion canadense griseum*) from 60 to 70 fathoms, and on July 5, 1923, a gang lifted 18 miles NE. ¾ E. of the same place from 80 to 100 fathoms had seven saugers and two 3-pound pike (*Esox lucius*). Virtually all the fish were alive, but the pike were very much emaciated. Probably they had been unable to see food in their novel environment.

Thus all the data show that the herring begin to come ashore in September and are at the height of abundance during October and November. In Green Bay and in Grand Traverse Bay some stay on the shoals under the ice, but it is not known that they remain along the shores of the lake in winter, and there are indications that they retire to deeper water. In early spring they come ashore again and are found here when the nets are set in early April. During June the catches dwindle, and after July 1 few herring are seen anywhere. A few stragglers occur on the shoals throughout the summer and also at depths of 60 fathoms and more, but the data we have indicate that the main schools are never in water deeper than 10 to 20 fathoms during the warmest months. It is possible that the schools are also pelagic at times in summer, as in Lake Superior.

BREEDING HABITS

In fall the herring migrate toward shore to spawn. Little is known by the fishermen as to when and where the eggs are laid. In Green Bay, off Oconto, Wis., males observed on November 17, 1920, were pearled, and about one-third of the females were nearly ripe. Only a few were spawning. The lifts were light at this time, however, which would indicate that spawning had not yet begun. R. F. Kleinke, at Menominee, Mich., says that the fish usually spawn toward the end of November in Green Bay, selecting sand bottom in 10 to 25 feet of water. Most of the spawning

grounds, he says, are on the Michigan shore. The Oconto shoals are much frequented on the Wisconsin side. In Grand Traverse Bay and at Port Washington, Wis., the fishermen quoted previously inform me that spawning usually is not at its height until November 20. The fish spawn at these places on sand along shore at depths of 10 to 25 feet and remain on the spawning grounds into December. Farther south the spawning season apparently is later, as F. C. Kimball, of Michigan City, says that herring taken in early December have not yet begun to spawn.

VALUE AS FOOD

The Michigan herring are in no way superior as food to those from Huron or Superior, except possibly those from the deep water of Green Bay, but good markets are nearer, and therefore smaller quantities can be marketed with profit. Most of the herring taken on the western and southern shores are sold fresh; but elsewhere, especially to the northward, where transportation facilities are not so good, many are salted.

ABUNDANCE

There are no data on the present abundance of the species, except such as exist in the minds of the fishermen. In two places, Beaver Island and Gros Cap, the fishermen say the herring are now commercially extinct, and they are said to be much less abundant at Grand Haven than formerly. No protection has been afforded the species in the way of closed seasons, and the size of mesh allowed for their capture in all States is near the minimum that would take a marketable fish, and it would not be surprising if the species had been seriously reduced in numbers everywhere. It appears, however, that in Lake Michigan, as in the other lakes, those areas in which they were most abundant originally still know them in quantities that foreshadow no immediate extermination.

Leucichthys artedi artedi and artedi manitoulinus of Lake Huron

Five species of herring have been reported from Lake Huron by Jordan and Evermann (1911)—*harengus*, *cisco huronius*, *manitoulinus*, *eriensis*, and *artedi*. The first two are very unsatisfactorily differentiated from one another by their authors. They have been separated by very few characters, and these I do not hold to be valid. (See p. 492.) The two names, then, may be taken jointly to represent the common herring of Lake Huron. *Manitoulinus* is a well-differentiated form, but is known to intergrade with the common herring and is here regarded only as a local race. The status of *albus* as the common form of Erie and of *eriensis* and their relation to *cisco huronius* are discussed on page 480, where reasons are given for treating all the forms of the shore herring of the Great Lakes as races under the specific caption of *artedi*.

The common herring of Lake Huron resembles very closely the rare blue-backed slender variety of Erie. There is present in the North Channel a form (*Leucichthys manitoulinus* of Jordan and Evermann; fig. 26) that approaches in shape the common Erie type, but in its extreme development it is nearer in its characters to the deep-water *nigripinnis* of Lake Huron than to any herring in the Great Lakes. The common forms of the herring of Lakes Erie, Michigan, and Huron are compared in their

chief characters below. The Michigan specimens are given as typical of *artedi* because there are only a few available examples of that form from Erie, and it has been shown that the forms from the two lakes are probably identical.

Gill rakers on the first branchial arch:
- Erie, *albus*, (41) 44–48 (53).[50]
- Michigan, *artedi*, (41) 46–50 (55).[51]
- Huron, *artedi*, (40) 45–50 (53).[52]

Lateral-line scales:
- Erie, *albus*, (64) 70–81 (89).
- Michigan, *artedi*, (68) 77–87 (94).
- Huron, *artedi*, (68) 76–86 (98).[52]

L/H:
- Erie, *albus*, (4.1) 4.4–4.7 (5.2).
- Michigan, *artedi*, (4.1) 4.3–4.5 (5.)
- Huron, *artedi*, (4) 4.3–4.6 (5).[53]

H/E:
- Erie, *albus*, (3.8) 4.2–4.5 (4.9).
- Michigan, *artedi*, (3.6) 4–4.2 (4.7).
- Huron, *artedi*, (3.7) 3.9–4.3 (5.1).

H/M:
- Erie, *albus*, (2.5) 2.7–2.9 (3.3).
- Michigan, *artedi*, (2.5) 2.7–3 (3.3).
- Huron, *artedi*, (2.6) 2.8–3 (3.3).

H/S:
- Erie, *albus*, (3.6) 3.8–4 (4.5).
- Michigan, *artedi*, (3.3) 3.7–4 (4.4).
- Huron, *artedi*, (3.5) 3.7–4 (4.3).

Pv/P:
- Erie, *albus*, (1.6) 1.9–2.1 (2.5).
- Michigan, *artedi*, (1.6) 1.9–2.2 (2.6).
- Huron, *artedi*, (1.7) 2–2.2 (2.6).

Av/V:
- Erie, *albus*, (1.4) 1.5–1.8 (2.1).
- Michigan, *artedi*, (1.4) 1.6–1.8 (2.3).
- Huron, *artedi*, (1.4) 1.6–1.8 (2.1).

L/D:
- Erie, *albus*, (2.8) 3.3–3.7 (4.8).
- Michigan, *artedi*, (3.6) 4–4.9 (5.3).
- Huron, *artedi*, (3.5) 4–4.7 (5.4).

These figures show that the Huron form is very like the *albus* form of Erie, except in body depth. The figures indicate that the former has possibly a few more gill rakers on the average, more scales in the lateral line, a larger eye, and much less body depth. The Huron fish seem to be very like the *artedi* of Lake Michigan and therefore may be given the same name. The inclusion of the extremely developed North Channel *manitoulinus* with the Huron specimens would lower the minimum value given in parentheses to the left in the case of L/H, H/E, H/M, Pv/P, Av/V, and L/D. As in every instance cited a proportion is involved, it follows that the North Channel individuals have a longer head, eye, maxillary, paired fins, and greater body depth.

The mandible has been found to be longer than the upper jaw in only 11 per cent of the Huron specimens and usually is equal or shorter, as in Lake Erie.

The color in life of most Huron specimens is very like that of the blueback of Erie, namely, deep blue green on the back, though often specimens are seen that are as pale as the common Erie type. The difference in coloration is particularly conspicuous when a school is seen swimming near the surface of the lake. A few will be lighter in color on the back than the rest. This, by the way, is no less true in any of the lakes. All Huron specimens, however, tend to show more pigmentation, particularly on the back and head. The ventrals, while often immaculate,

[50] Figures of Lake Erie *albus* for proportions are based on an examination of 148 specimens ranging in length from 225 to 402 millimeters, those for gill rakers on 298, and for lateral-line scales on 735.

[51] Figures for Lake Michigan *artedi* are given for 148 specimens ranging in length from 225 to 367 millimeters, except those for gill rakers and lateral-line scales, which are based on 391 fish.

[52] Figures for Lake Huron so designated are based on an examination of 343 specimens ranging in length from 125 to 371 millimeters. Those figures that deal with proportions are based on an examination of 215 specimens ranging in length from 225 to 371 millimeters.

[53] From proportional figures for Huron the 20 specimens of *manitoulinus* have been deducted.

particularly in Saginaw Bay and southward, often show a sprinkling of pigment; and at the north end of the lake and in the North Channel and in Georgian Bay individuals very frequently show pigment on all the abdominal fins. The herring taken in the North Channel at Cutler (subspecies *manitoulinus*) are considerably darker than those collected elsewhere. In such individuals the color of the back in life is blue green obscured by heavy pigmentation, which extends onto the sides of the body and of the head. The cranium is deep blue black, as is the snout. The abdominal fins are usually very heavily pigmented, especially on the longest rays, and the dorsal and caudal are likewise very dark. Specimens are taken frequently elsewhere in the North Channel which show an approach to these melanistic individuals, and specimens with heavily pigmented paired fins are not unusual in Lake Huron, particularly in the northern waters and in Georgian Bay.

All males and probably all females show pearl organs in the breeding season, which do not differ in their development from those described for the Lake Erie form.

VARIATIONS

Racial variations.—There is a wide variation in all characters exhibited by specimens from the same school, as may be seen in Table 71. The specimens from certain localities often show distinct tendencies to vary in certain directions, but, with the exception of the Cutler herring, none of these local forms have varied so far that they are conspicuously different from their neighbors. Many of these forms, however, would certainly show average differences in certain characters, but there have been so few specimens collected from any locality (except from Saginaw Bay) that it is not possible to give here a serious treatment of these differences. The fact that most of the characters that would be involved in such a comparison are proportional expressions, which vary in quality with the size of the individual, further reduces the significance of a study based on a few individuals. It may be worth while to point out, however, that what data I have indicate that the individuals from the North Channel will be found to have proportionally larger heads and eyes, darker color, and possibly shorter paired fins than those from Lake Huron proper and Georgian Bay.

I do not agree with the findings of Jordan and Evermann (1911), who, in describing *harengus* as occurring in Lake Huron but particularly in Saginaw and Georgian Bays, state that it differs from *cisco huronius* of Lake Huron proper and of Georgian Bay in having a gray color, less cylindrical body, smaller size, and especially in having a much smaller adipose fin. In point of color I have observed already that an occasional specimen may have a paler back, be it found in what part of the lake it may; but I have not been able, in my examination of several thousand individuals, to confirm the general observations of these authors as to the color differences of the bay forms and those of the open lake, nor have I been able to find that there were differences in the degree of lateral compression of the body. As for size, it is true that the fish in Saginaw Bay and some parts of Georgian Bay are of small size as a rule, but this is not always the case, for in the fall of 1917 in Saginaw Bay and in the fall of 1919 at Killarney, in Georgian Bay, I found a run of fish larger than usual. Furthermore, size can not be considered in general a specific character, because environmental conditions usually control the average or maximum size of the fish in a

given locality. In the case of Saginaw Bay, where there has been extensive and continued operation of nets of a legally fixed mesh, it might be expected that the average size of the fish taken would be reduced. My contention receives the support of Doctor Van Oosten, also, who finds that most of the herring taken in Saginaw Bay are very young fish. The adipose fin is a rudimentary character and is too variable to have specific value. (See Table 71.)

Typical examples of the Cutler form are so different from the typical herring of Huron that they might readily be taken for a distinct species; in fact, they are almost identical with the deep-water blackfin, *nigripinnis*, in those characters that can be expressed numerically. They intergrade, however, with the typical herring of the channel and behave exactly like them, so that there is no doubt that they belong to the species group *artedi*. Furthermore, all those characters that have varied to produce this form are those that a study of *artedi* elsewhere shows to be fluctuating. All the herring of Lake Huron 225 millimeters or more in length are compared below with 20 individuals taken at Cutler:[54]

Gill rakers on the first branchial arch:
- Huron, (40) 45–50 (53).
- Cutler, (43) 44–47 (51).

Lateral-line scales:
- Huron, (68) 76–86 (98).
- Cutler, (69) 71–77 (81).

L/H:
- Huron, (4) 4.3–4.6 (5).
- Cutler, (3.9) 4–4.2 (4.3).

H/E:
- Huron, (3.7) 4–4.3 (5.1).
- Cutler, (3.4) 3.7–3.8 (4).

H/M:
- Huron, (2.6) 2.8–3 (3.3).
- Cutler, (2.5) 2.6–2.8.

H/S:
- Huron, (3.5) 3.7–4 (4.3).
- Cutler, (3.7) 3.8–4 (4.2).

Pv/P:
- Huron, (1.7) 2–2.2 (2.6).
- Cutler, (1.5) 1.6–1.7 (1.8).

Av/V:
- Huron, (1.4) 1.6–1.8 (2.1).
- Cutler, (1.1) 1.3–1.4 (1.6).

L/D:
- Huron, (3.5) 4–4.7 (5.4).
- Cutler, (3.4) 3.5–3.8 (4).

It appears from these figures that the Cutler form has a longer head, eye, maxillary, and paired fins, fewer lateral-line scales, and a much deeper body than the *artedi* of Huron. The body is also much more compressed and, as has been stated on page 492, much more pigmented throughout, and there are fewer scale rows. The shape, as seen from the side, is elliptical as in the others, and the lower jaw is usually equal to or somewhat shorter than the upper. Ten specimens are compared extensively in Table 71 in all the characters that can be expressed numerically.

Intergrades with the *artedi* form have been taken at Blind River on November 8, 1917, and at Kagawong, off Clapperton Island, on November 10, 1917. Those characters in which the two forms differ are given for these specimens in Table 72. The letter A follows the characters that approach the *artedi* type, the letter M those that approach the *manitoulinus* type.

Size variations.—Herring change but slightly in their systematic characters with growth. A comparison of the principal proportional characters follows. The fish are divided according as they are over or under 225 millimeters in length. In the one group there are 215 individuals, in the other 133. Detailed figures for several

[54] Jordan and Evermann (1911) say of the type of *L. manitoulinus:* "Type No. 64670, U. S. National Museum, a specimen 11 inches long from Blind River, North Channel, Lake Huron."

of these characters are given in Tables 8 to 11, and in Table 71, 10 small specimens under 200 millimeters in length are compared extensively.

L/H:
- Large fish, (4) 4.3–4.6 (5).
- Small fish, (4) 4.2–4.5 (4.8).

H/E:
- Large fish, (3.7) 3.9–4.3 (5.1).
- Small fish, (3.6) 3.8–4 (4.3).

H/M:
- Large fish, (2.6) 2.8–3 (3.3).
- Small fish, (2.5) 2.7–2.9 (3.2).

H/S:
- Large fish, (3.5) 3.7–4 (4.3).
- Small fish, (3.3) 3.6–3.9 (4.2).

Pv/P:
- Large fish, (1.7) 2–2.2 (2.6).
- Small fish, (1.7) 1.9–2.1 (2.3).

Av/V:
- Large fish, (1.4) 1.6–1.8 (2.1).
- Small fish, (1.3) 1.6–1.7 (1.9).

L/D:
- Large fish, (3.5) 4–4.7 (5.4).
- Small fish, (3.6) 4.2–4.9 (5.8).

Thus, small herring seem to have proportionally a somewhat larger head, eye, maxillary, snout, and possibly paired fins, and less depth than large fish of the same species.

Individuals as small as 160 millimeters have been found to be sexually mature, and a few have also been found immature at 200 millimeters, but usually specimens over 170 millimeters have exhibited maturing gonads. A closer relation, of course, will be found between age and maturity.

COMPARISONS

Artedi resembles closely only *nigripinnis*. Juvenile examples, however, might be confused with *hoyi*. A discussion of the differences between *artedi* and the other species of Leucichthys occurring in Lake Huron is given under this heading in the accounts of the various species.

GEOGRAPHICAL DISTRIBUTION

Herring occur in schools, and these are found out of virtually every port on Lake Huron, in the North Channel, and Georgian Bay. No commercial fishing operations whatever are conducted for herring from many of the fishing ports, and from but few are the operations carried on extensively; but whether fished for or not, the herring schools can not escape observation entirely. Some individuals always become entangled in the gill and pound nets set for whitefish and trout, while schools frequently enter harbors, where they may be captured by hand lines, or are encountered in the open lake. On the Canadian shore very few herring are taken for market. The catch of herring on the American shore is greatest in Saginaw Bay, while the region from Thunder Bay to Middle Island ranks second. The rest of the ports take the fish in relatively insignificant quantities. I have collected specimens from nearly every port visited. The data for these are given in Table 70 and are platted in Figure 5.

METHODS OF CAPTURE

Herring are caught both in pound and gill nets. They follow the leads of the pound nets readily, even though the mesh of these leads is so coarse that they could swim through them easily. I have seen them time and again swimming about in the pots of the whitefish pounds, the mesh of which is coarse enough to permit them to

pass out; but they escape only when the pot is lifted. When it is desired to retain herring in the pounds the mesh of the pot must be reduced to about 2 inches. When gill nets are used (which is chiefly in the fall, when the fish are most abundant) the mesh in 2½ to 2¾ inches, or even 3 inches, depending on the locality. The question of the mesh that should be legal for herring has been much agitated. The fishermen claim that the herring always run small out of certain ports and that for this reason at these ports nets of smaller mesh are required. I have been able to collect no data on this subject, but I believe that probably there is no reason to doubt the statement of the fishermen.

SEASONAL MOVEMENTS

Like the whitefish, the herring schools move inshore in the early fall and out again in late spring. It is possible that for some localities, at least, there are two such movements—that the fish come in and go out both in fall and spring instead of remaining inshore all winter. There are not yet enough data on winter fishing to decide this point. To what these migrations are due has not been determined, but the fishermen believe that they are governed by changes in water temperature. The data collected from the fishermen bearing on these migrations all indicate that this explanation is at least plausible. These data are summed up in the following paragraphs:

Data on occurrence in the herring nets in spring and fall.—At Cheboygan, Mich., according to Louis Peets, the herring are in 20 feet of water on sand bottom from the middle of October until he pulls in his pounds (the last of November). In spring he finds them on these grounds again, but in diminished numbers. They remain until about June. Alfred Roberts says the behavior of the species is about the same at Harbor Beach, Mich. During June, however, when the main school has left, a school of larger herring comes in. These fish gill in 2½-inch nets, while for the others 2 to 2¼ inch nets are required. The large fish come in, the fishermen think, to feed on the "June flies," which are present in swarms at that time of the year. The June fly, from the description of the fishermen, seems to be a large Chironomus. Bert Andrews, of Port Huron, Mich., gives the following account of the species for that port:

"From the opening of navigation (April 1) until the end of June, and from the middle of October until ice forms, herring are taken out of Port Huron in pound nets in 25 feet of water. The largest numbers are caught from November 10 to the end of the month. Some are taken in 20 feet of water in gill nets all winter." At Middle Island and in Thunder Bay, from the middle of October until freezing, the Alpena and Rogers boats (according to the statements of the pilots of these boats) set 2¾-inch gill nets in 3 to 5 fathoms on gravel and bowlders. If conditions are favorable, the Alpena tugs set the nets back for a few lifts toward the end of March or the first of April. Records of James Morley show that about the middle of May the herring begin to come into the pound nets in 25 feet of water about Sulphur Island. They are gone from the end of July to the end of September. From the end of September until the nets are pulled out (in the middle of November) they are present again. The quantity taken at Sulphur Island is not great. Records

show great fluctuation in the abundance of the fish in the nets from day to day in fall and spring and in the date of appearance and disappearance with the season.

The foregoing records are for the main lake, but reports concerning the Saginaw Bay schools, while more detailed, are little different in character. I am indebted to John Trudell and John Lixy, of East Tawas, for the records for that port and to W. P. Cavanaugh and Fabian Willets, of Bay City, for the records for the rest of the bay. The herring apparently move into the bay from the lake. About the middle of October the schools begin to appear in the pounds in 10 to 40 feet of water on clay bottom off East Tawas. A few days later they appear in the pounds on sand at White Stone Point, and about the first of November they are along the south shore of the bay. The fish remain at each of the above localities, except East Tawas, to spawn. At East Tawas only the small fish are left after November 20. Near the mouth of the bay some are known to remain under the ice. In the spring they are not found commonly at the south end of the bay. At Point au Gres none appear until April 20 to 25. At East Tawas they appear by May 15 and stay until July 15. At the Charity Islands they are said to occur until June 10 to 15. Huge swarms of small herring 1½ or 2 inches long are said to precede the runs of larger ones by a week in the fall along the shore from East Tawas to White Stone Point. They are not so common south of the latter point. There are few of these small fish in the spring. No one has identified these small fish positively, and they may be species of Notropis, which abound on the sandy shores of the lake.

There are few sources of data on the behavior of the herring on the Canadian shore, but such information as has been collected indicates that the Canadian fish behave as their brethren on the other side of the lake. At Wiarton, in Georgian Bay, Dan MacDonald says that the herring appear in his pounds in Colpoys Bay at any time during the fishing season until October, but that the biggest run is during the month of June. Throughout the season, however, the schools come and go without apparent reason. The hydrographic map shows only a very narrow shelf along the shore in this region, which possibly supports little food, and the herring thus are driven to seek food in the open bay. Their absence in the fall is due, no doubt, to the lack of suitable breeding grounds in Colpoys Bay. The bottom here is chiefly mud. The race at Cutler (*manitoulinus*) in the North Channel is occasionally the object of commercial fishing operations, particularly in the fall. Alex Purvis, of Gore Bay, who has fished the Cutler herring, says that one year about November 5 they were taken 2 miles outside of Johns Island, toward Gore Bay, in 8 to 10 fathoms. By the 10th they were around the islands in Cutler Bay in 12 feet of water. They enter the bay to spawn and usually remain about three weeks. After spawning they leave abruptly and are seen no more until the nets are put in in the spring. After the month of May they are gone once more until the following November. Where they spend the remaining portion of the year no one knows. It might be inferred from their dark coloration that they do not stray far from the neighborhood of the Spanish River, whose muskeg waters empty into the bay.

Data on summer occurrence.—The herring are not followed by fishermen after they move out of shallow water in June. Only a few casual observations made by the fishermen and by me are available for the period during which the herring are offshore. Various fishermen have told me that occasionally they see schools swim-

ming in the open lake during the summer. They recognize the fish by their blue green color. The fishermen at Tobermory say that they may be caught in numbers in August in 14 to 16 fathoms in the channel between Yeo and FitzWilliam Islands in Georgian Bay. My own records from off Alpena, Mich., in September, 1917, seem to confirm those of the Tobermory fishermen. On September 8, 1917, I found a few small individuals (of which nine were preserved) in the 1½-inch nets at 30 fathoms (record 6). On September 10, 3 and 12 specimens were entangled in 4½-inch nets set at 20 and 15 fathoms, respectively (records 7 and 8). On September 12 one was taken in 15 to 17 fathoms (record 9). On September 14 eight were taken in these nets at 24 fathoms (record 10). On September 17 three were taken at 15 fathoms (record 11). On both September 22 and 26 six were taken in 17 fathoms (records 12 and 13). On September 20 and 25 herring were found in the stomachs of trout taken from 10 to 15 fathoms off Alpena. On September 5 they had not yet come as shallow as 3 fathoms (record 5). On September 24 a gang of 2¾-inch nets set from the can buoy to Sulphur Island in 8 to 10 fathoms three nights out got about 300 pounds of herring (record 14). On September 27, in the same place, 1,200 pounds were taken. On October 14, 1917, two herring were taken at 35 fathoms off Rogers, Mich., in a gang of 2¾-inch nets (record 3). These two individuals were the only ones taken, and their occurrence at this depth has no significance. It is possible, of course, that these specimens, as well as the occasional specimens previously mentioned, may have become entangled in the nets while the latter were being set or lifted; but in that case it might be expected that they would be found regularly in the chub lifts, also, unless, of course, the schools do not venture offshore as far as the chub grounds.

The records of the fishermen covering fishing operations for the herring thus show that they begin to come in to 20 to 30 feet of water in numbers sufficient for commercial purposes about the middle of October. They are caught then until the nets are pulled out on account of the weather, the last of November or the first of December. Probably they remain under the ice all winter on these grounds. The fact that a few are taken in the gill nets under the ice off Port Huron and in Saginaw Bay seems to warrant this assumption. In the spring, as soon as navigation opens, the nets take them on the same grounds as in the fall. The length of time during which the schools remain on the shoals varies with the locality. At Cheboygan and Cutler they are gone about June 1. At Port Huron, Harbor Beach, and Saginaw Bay they remain until about the last of June. At Alpena they may stay until the end of July. Of course, here as elsewhere on the lake an occasional specimen may be taken on the shoals almost all summer. After leaving the shoals the herring probably swim near the surface, as do the trout in June and July, and repair later to deep water. In August they are known at 15 to 16 fathoms between Yeo and FitzWilliam Islands and at similar depths off Alpena from September 10 to 26. A few records of the fishing tugs show them moving into 8 to 10 fathoms toward the end of September. Thirty-five fathoms is the maximum depth from which the species is known in the lake. Two specimens were taken at this depth from a gang of chub nets off Rogers on October 14, 1917.

BREEDING HABITS

The fall inshore migration is for the purpose of spawning. However, the fishermen can give no information as to when the fish actually deposit their eggs. Certainly they spawn in November, for a few males taken at Bay City on October 25, 1917, showed indications of pearls and females were nearly ripe, and the males taken at Cutler on November 11, 1917, were heavily pearled, while the two females were spawning. The herring fishermen say also that the catches are heaviest in November, which indicates that the individuals of the school are more numerous or more easily captured than usual. According to the majority of the reports, gravel or sand are preferred by the spawning fish.

VALUE AS FOOD

The flesh of the herring is dry and is considered by some as flavorless. Others find it very palatable. Whatever may or may not be its merits in this respect, the fishermen until recently received only 2 or 3 cents per pound, or less, for herring, and consequently they did not set nets for them when other fish were available.

ABUNDANCE

In view of the fact that market conditions have not encouraged the capture of herring, it appears their numbers have not been reduced seriously. At least in Saginaw Bay, where fishing has been most intensive, the fishermen report no decrease in late years. There is no doubt, however, that fish are much scarcer now than they were 25 years ago, and it is certain also that many more and better nets are being used from year to year. There are, of course, "off seasons" when, for various reasons, not many fish are taken in the bay, but on the whole there have always been plenty of herring to be had. This is true in spite of the fact that the fish have not been protected by a closed season and that few plants of fry have been made. There are, it seems, immense areas in the bay that are suitable breeding grounds for the species.

FOOD

From the examination (made by Carl L. Hubbs, of the Michigan University Museum) of the stomachs of 78 individuals collected in gill nets at an average depth of 10 fathoms off Alpena, Mich., from September 20 to October 16, 1917, plankton Entomostraca are found to comprise the bulk of the food. Two specimens taken in gill nets off Blind River, Ontario, on October 12, 1917, had eaten only Entomostraca. Thirty specimens collected from pound nets set in 5 fathoms off Bay City, Mich., on October 23, 1917, were feeding chiefly on larval May flies (Hexagenia). Other articles of food ingested in insignificant quantities by the Alpena and Bay City fish include larval Chironomidæ, Corixidæ, and Trichoptera, Asellus, fish scales, fishes, wood fragments, and algæ. Stomachs of 50 specimens taken in the summer of 1921 in Douglas Lake, Cheboygan County, Mich., and 50 specimens from Portage Lake, Washtenaw County, Mich., taken from July 1 to 15, 1920, in 7 to 10 fathoms, yield the same findings as in the case of the Alpena fish. F. M. Gaige, of the Michigan University Museum, reports that on September 26, 1910, the stomachs of herring taken by the fishermen off the Charity Islands in Saginaw Bay were full of the winged ants that abounded in swarms at that season.

The food of the herring varies, no doubt, with the season. When the schools are inshore they probably feed heavily on the larval insects that are present in the shallow water and on such other items of food as come in their way. At such times they are known to take the hook. Small spoons, pearl buttons, or minnows are the commonest baits used. At other times their food is probably largely plankton organisms, as they are not known to migrate in Lake Huron to the depths inhabited by Mysis, the chief food element of the deep-water Leucichthys, and no insect larvæ occur except along the shores.

Leucichthys artedi artedi and artedi albus of Lake Superior

The herring population of Lake Superior is constituted of the two types that are found in Lake Erie, except that the elongated terete form, which is rare in Erie, is the most abundant, and the deeper-bodied form, which is the predominating form of Erie, probably is confined to the warm bays on the north shore. In general, the systematic characters of the forms that occur in the two lakes are not very different. All collected specimens of both races are grouped together for each lake in the comparisons of the various systematic characters given below. There are available so few specimens of the rare types in both lakes that it does not seem worth while to separate them for comparison more than has been done in Tables 67 and 74, where 20 large *albus* and 10 large *artedi* for Lake Erie and 4 large *albus* and 6 large *artedi* for Superior are analyzed in detail.

Gill rakers on the first branchial arch:
- Erie, (41) 44–48 (53).[55]
- Superior, 38 (41) 45–48 (53).[56]

Laterial-line scales:
- Erie, (64) 71–81 (89).
- Superior, (72) 84–93 (105).[56]

L/H:
- Erie, (4.1) 4.3–4.7 (5.2).
- Superior, (4.1) 4.3–4.6 (5.1).

H/M:
- Erie, (2.5) 2.7–2.9 (3.3).
- Superior, (2.5) 2.7–3 (3.1).

H/S:
- Erie, (3.6) 3.8–4 (4.5).
- Superior, (3.4) 3.6–3.9 (4.3).

Pv/P:
- Erie, (1.6) 1.9–2.1 (2.5).
- Superior, (1.7) 2–2.2 (2.8).

Av/V:
- Erie, (1.4) 1.6–1.8 (2.1).
- Superior, (1.3) 1.6–1.8 (2.3).

L/D:
- Erie, (2.8) 3.3–3.7 (4.8).
- Superior, (3.7) 4.3–5 (5.9).

The data indicate that the Superior *artedi* has much less body depth and more lateral-line scales than the *albus* of Erie. The pectorals also are somewhat shorter and the snout usually a trifle longer. The counts indicate that the fin rays are, on the average, more numerous in the Superior fish, but these characters have not been investigated more closely than has been shown in Tables 67 and 74. The scale rows, of course, are also more numerous in the *artedi* form, wherever it may occur.

Comparing the two types of the two lakes with one another, it appears that the Superior *artedi* race probably has more lateral-line scales than individuals of that type in Lake Erie. Individuals of the *albus* of Superior can be matched exactly

[55] These figures for Lake Erie are given for 313 specimens ranging in length from 128 to 402 millimeters. Those for scales are based on 750 specimens of the same size range, but all figures for proportions are based on only 163 of the specimens 225 millimeters or more in length.

[56] These figures for Lake Superior are based on an examination of 257 specimens, which range in length from 135 to 435 millimeters. All figures dealing with proportions are given only for the specimens of this group 225 millimeters long or longer, which are 185 in number.

with Lake Erie specimens, except that the eye regularly may be a trifle larger in the former.

The color in life is like that of the Erie form, except that the deep blue green is the commonest shade. As in Lake Huron, fish with pale backs occur in any school. The body, especially the back and the cranium, is also more heavily pigmented as a rule. The fins average a trifle darker, too, except possibly the ventrals and the anal.

Pearl organs are developed in the species, but the specimens obtained in Thunder Bay on November 25, 1922, were so rubbed in transit that the extent of the development of nuptial adornment could not be ascertained. It is probably no different from that described for the species in the other lakes.

VARIATIONS

Racial variations.—There are two types of herring in Lake Superior, as there are in Lake Erie—the elongated, subterete form and the deeper, more compressed one. The latter closely resembles the common Erie type and occurs commonly, so far as is known, only in the shallow, warm bays at the north end of the lake. (Hankinson, 1916, Pl. XXVIII, *A*, gives a photograph of a specimen taken off Whitefish Point, Mich., on the south shore.) These bays, however, are connected freely with the main lake, and the long, slender type is therefore also of common occurrence in their waters, as are, of course, intergrades between the two. In fact, typical *albus* have not been found as commonly as the others, as will appear from the figures below. No careful study has been made of the races of herring in this or any other area, but in comparing 135 specimens from the north bay region with 118 specimens taken in the main lake on the eastern and southern shores,[57] certain tendencies of variation are indicated, which are expressed in some measure by the following:

Lateral-line scales:
- North bays, (72) 79–93 (100), with 19 per cent less than 80.
- Lake, (76) 84–92 (105), with 1 per cent less than 80.

Pv/P:
- North bays, (1.6) 1.8–2.2 (2.6), with 30 per cent less than 2.0.
- Lake, (1.8) 2.1–2.3 (2.5), with 9 per cent less than 2.0.

Av/V:
- North bays, (1.5) 1.6–1.8 (2), with 16 per cent less than 1.6.
- Lake, (1.3) 1.6–1.9 (2), with 6 per cent less than 1.6.

The figures show that the range is about the same for both groups, but this is due to the fact that the "north bays" group is made up of all fish that have been collected on the north shore, regardless of whether they probably were regular inhabitants of the bays; and the figures are interesting only inasmuch as they show tendencies of the bay fish to vary in the direction of the common Erie type. In Table 74 the first five specimens in the group of individuals 225 millimeters or more in length, four of them *albus* and one *artedi*, are from the north bays; the other five are *artedi* from the open lake. These two groups also show a difference in those characters that have been mentioned above and indicate further that the northern fish are deeper bodied.

[57] Neither group contains specimens assorted according to size, but the proportion of specimens under 225 millimeters in length is about the same for both.

Size variations.—In Table 74, 10 specimens less than 200 millimeters in length and 10 specimens more than 225 millimeters in length have been compared extensively, and in Tables 8 to 11 all the individuals less than 225 millimeters are compared in certain characters with those of 225 millimeters or more. Figures for the more important systematic characters that can be expressed numerically are abstracted below:

L/H:
- Large fish, (4.1) 4.3–4.7 (5.2).
- Small fish, (4) 4.2–4.6 (4.8).

H/E:
- Large fish, (3.6) 4.1–4.4 (5.1).
- Small fish, (3.4) 4–4.2 (4.5).

H/M:
- Large fish, (2.5) 2.7–3 (3.1).
- Small fish, (2.5) 2.7–3 (3.2).

H/S:
- Large fish, (3.4) 3.6–3.9 (4.3).
- Small fish, (3.5) 3.6–3.9 (4.1).

Pv/P:
- Large fish, (1.7) 2–2.2 (2.8).
- Small fish, (1.6) 1.9–2.2 (2.3).

Av/V:
- Large fish, (1.3) 1.6–1.8 (2.3).
- Small fish, (1.4) 1.5–1.8 (1.9).

L/D:
- Large fish, (3.7) 4.3–5 (5.9).
- Small fish, (4) 4.6–5 (5.2).

A study of these tables shows that the differences between the two groups is slight. The head and eye are proportionally somewhat larger and the depth somewhat less in smaller individuals. The paired fins possibly are also a trifle longer.

No specimens smaller than 190 millimeters have been found to be sexually mature, and the majority of those under 200 millimeters have been immature.

COMPARISONS

Typical *artedi* may be distinguished readily from any other Leucichthys in the lake. The differences between *artedi* and the other species of Leucichthys are given under the heading "Comparisons" in the accounts of these species.

GEOGRAPHICAL DISTRIBUTION

The herring of Superior occur in schools, as in the other Great Lakes, and the species is as widely distributed in Lake Superior. At Bayfield, Wis., and Port Arthur, Ontario, they are so abundant that extensive fishing operations are conducted for them during the fall; and at several other ports, particularly along the west shore, they are taken at some time of the season in commercial quantities. Specimens have been collected from every one of the 12 ports visited. The data for these are given in Table 73 and are shown platted on the map of the lake in Figure 3.

MODE OF CAPTURE

Virtually all herring caught in the lake are taken by means of gill nets. Except in Michigan, where 2¾-inch nets usually are employed, the regulation mesh is 2½ or 2⅜ inches. The nets are used on the bottom, as in the other upper lakes, except in the western waters, where it has been the custom for several decades to float them below the surface. This practice has been followed not only in summer but also in fall. The descent into deep water on the western Minnesota shore is precipitous virtually everywhere, and this hydrographic condition no doubt has forced the herring to a more strictly pelagic life than in localities where shoals obtain. The

methods of floating nets are in principle like those employed on Lake Erie, but it is interesting that they were put into practice first on Lake Superior and were arrived at independently on the other lakes.

SEASONAL MOVEMENTS

The herring schools appear to spend more of their time near the surface in Lake Superior than in the other lakes, probably because its water is colder, and the seasonal inshore movements are not so pronounced. However, there is a definite congregation of the species on the shores in late fall, and it is at this time only that the schools become the object of intensive fishing operations.

Data on occurrence in the herring nets in fall.—At Grand Marais, Mich., according to William Doolan and Charles MacDonald, the herring come ashore on sand toward the end of October and remain until the ice forms in early December. At times, at least, in the fall they are in water as shallow as 3 or 4 fathoms. They are seen seldom under the ice, the fishermen say. At Marquette, Mich., the schools come ashore east to northwest of the city on sand bottom, according to Will Parker. They are present in commercial quantities about November 10 and remain until about the first week in December. At first they are in 8 to 9 fathoms of water but later move out to 14 or even 20. The account given for Ontonagon, Mich., by Earl Couture, and for the Apostle Islands, Wis., by M. B. Johnson, of Bayfield, are virtually the same as for Marquette, except that around the Apostle Islands the fish frequent somewhat shallower water. James Scott informs me that at Grand Marais, Minn., the fishermen begin commercial operations about the 1st of October. The nets are floated offshore at that time, about 4 fathoms below the surface. The lifts are heaviest in November, and during this month the nets are lowered to about 7 fathoms. Fishing is discontinued in early December. In Thunder Bay, out of Port Arthur and Fort William, Ontario, the schools begin moving in from the west between Pie Island and the mainland about the middle of November and spread northward and eastward. They remain until early December and depart then rather suddenly over the same course. While in the bay they are taken at depths of 6 to 25 fathoms on mud and clay bottom. Commercial fishing operations for the species in Thunder Bay date from the Great War, and almost incredible quantities were taken by the virgin fisheries. John and Lew Maloney, James and Frank Gerow, and Oscar Anderson, of Port Arthur, affirm the correctness of the above account.

Data on occurrence at other seasons.—At Marquette, Mich., W. A. Morrison says the herring are present in commercial quantities in his pound nets in 30 feet only for a short period in late June. At Grand Marais, Minn., according to the testimony of James Scott, they are fished for during the year in floated nets a mile or more offshore, except, of course, in the fall and for a short period in late July and early August, when they are hard on the beach. On July 17 and 18 schools of young of the year were seined by me at the mouth of the Devils Track River and in the Grand Marais Harbor (records 13 and 14). No older individuals were included in the seine hauls, but they could have avoided the net easily. Hankinson (1914) got fingerlings on the beach at Whitefish Point in mid-August, 1913. Fishermen out of most of the ports visited believe they have seen schools of herring swimming near the surface in the open lake during the summer months, and those who fish pound nets for trout

and whitefish have recollections of seeing herring in the pot before the net is lifted during most of the pound-net season. As no herring are taken for commercial purposes during the summer, nothing else is known of the abundance of these fish at that season.

My records show that occasional specimens occurred in the pound nets on the north shore of the lake in Black Bay on July 20, 1922, in Moffat Strait and off Armour Point on August 10, 1922, on the east shore in Batchawanna Bay on June 17, 1922, and on the south shore in Marquette Bay on August 9, 1921 (records 15, 24, 25, 29, and 5). During the summer season my 2½ and 2¾ inch nets, which were set for deep-water Leucichthys, recorded a few stragglers at depths of 10 to 100 fathoms, namely, on June 14, 1922, 10 miles NW. by W. ¼ W. of Point Iroquois Light in Whitefish Bay in 38 fathoms (record 1); on August 5, 1921, 31 miles N. ¾ E. and on August 11, 1921, 18 miles NE. by N. of Marquette, Mich., in 100 to 80 fathoms (records 4 and 6); on August 24, 1921, 21 miles west, and on August 25, 1921, 6 miles NNW. of Ontonagon, Mich., in 15 to 45 and 20 to 38 fathoms, respectively (records 9 and 10); on July 11, 1922, between Cat and South Twin Islands in 15 to 20 fathoms (record 11); on July 17, 1922, 20 miles NE. by E. of Duluth, Minn., in 30 to 40 fathoms (record 12); on September 15, 1923, off Silver Island in 14 fathoms and in Thunder Bay off Thunder Cape in 31 fathoms; on September 17, 1923, in Thunder Bay inside the Welcome Islands in 11 fathoms; on September 19, 1923, in Thunder Bay off Sawyer Bay in 49 fathoms (records 17 to 20); on October 4, 1921, off Bread Rock in 80 to 90 fathoms (record 22); on September 25, 1923, in Moffat Strait in 13 to 14 fathoms (record 26); and on June 26, 1922, off Alona Bay in 60 fathoms (record 28). A few specimens were taken, also, entangled in the 4½-inch trout nets on August 16, 1921, 54 miles W. by N. of Ontonagon, Mich., in 25 to 80 fathoms; on June 19, 1922, in 15 to 35 fathoms, 6 miles northeast off the east end light of Michipicoten Island (records 8 and 27).

It has been pointed out before on preceding pages that fish may become entangled in the netting while it is sinking to the bottom, and the occurrence of individuals of the species in nets at extreme depths is therefore possibly accidental. Whether or no, many instances can be cited of stragglers of a shallow-water form occurring outside their normal depth range, and it would not be surprising if it were found that the herring at times do frequent profound depths.

All the accumulated data show that the herring come ashore in the fall and are present in commercial quantities from about the first or middle of November until early December. (It is noteworthy that the migration is later than or as late as in the lower lakes of the Great Lakes series, where the water probably cools more slowly.) In most localities they depart from the shores before winter and generally are not pursued thereafter until the following fall on account of the presence of more valuable species. An inshore migration in early summer is reported for some localities, and it is probably general, but at any rate the consensus of opinion of the fishermen and the meager data I personally have collected indicate that the schools do not go far below the surface during the warmer months. In the lower lakes the herring avoid the shoals only in the warmest weather and in winter, but in Superior the shoals probably seldom become warmer than is pleasant for them, and for this reason

they can be caught, in some numbers at least, in the pound nets all summer. There is probably also a close relation between temperature and their food, but this matter is not yet understood.

It may be seen from Table 13 that the waters of Lake Superior probably never become very warm, compared with those of other lakes in the same latitude. The warmest temperatures, it appears, are recorded from Black Bay, Simpson Channel, and Moffat Strait, where conditions are much more tempered than in the open lake; but even here the highest surface reading of 16.3° is less than one of 19.5° recorded from a location in Lake Nipigon some 75 miles farther north two weeks earlier in the season. It is seen, also, that the temperature, even in midsummer, drops off rapidly below the surface, except in Black Bay, which is so shallow and isolated that its conditions approach those of an inland lake, so that at 4 fathoms in Moffat Strait and Armour Harbor the temperature readings are 9.7° and 9.8°, and at 5 fathoms in Simpson Channel the thermometer reads 6.6° (records 22, 25, and 15). It is apparent, then, that the herring do not have to undertake a very extensive vertical migration to find cold water, and that if food is present near the surface there are probably no other physical factors that deter them from taking advantage of it.

BREEDING HABITS

The inshore fall migration is for the purpose of spawning. The grounds frequented by the largest schools are those around the Apostle Islands and in Thunder Bay. Apparently there are also favorable areas for spawning along the Minnesota shore, but they must be quite restricted in area and must extend along the shore. There are doubtless many grounds of less importance than these all along the lake shore. The bottom frequented varies from clay and mud in Thunder Bay to gravel and bowlders along the Minnesota shore. Sand is selected commonly on the south shore, probably because the shoals are sandy in this area. The depth of spawning varies, according to the fishermen, from a few feet to 25 fathoms. The statement of James Scott that the nets are floated during the spawning season 7 fathoms below the surface indicates that possibly spawning takes place off the bottom. The apparent indifference of the species to the character of bottom may support this view. The spawning season usually embraces about the last two weeks of November.

VALUE AS FOOD

The herring of Lake Superior are, in large measure, salted in kegs, but some are frozen for consumption in the fresh state. The quality probably is not materially different from that of the Michigan or Huron varieties.

ABUNDANCE

The herring fisheries around the Apostle Islands are old and are famous throughout the lake region for their productiveness. Those in Canadian waters, situated chiefly in Thunder Bay, are not much more than 10 years old. In years past the herring have been taken in quantities sufficient only to supply the demands of a class of trade that wanted cheap salt or fresh fish, and the prices paid the fishermen have been so low that they could afford to fish only because fish could be captured easily

and abundantly. Even under such conditions the herring have been much reduced in numbers, and with the increased effort that is certain to accompany the ever-increasing prices paid for these fish the species stands in danger of being decimated.

Leucichthys artedi of Lake Nipigon

The Lake Nipigon herring is similar to the Erie form, except that it is not known to grow so large. The largest specimen seen by me measured only 253 millimeters, while in Lake Erie individuals of more than 300 millimeters are common. The principal characters of systematic value that can be expressed numerically are compared below for the forms of the two lakes. On account of the small size of the Nipigon specimens the group of less than 225 millimeters is compared with the similar group from Erie (all of them necessarily *albus*, as no small *artedi* were collected in Lake Erie) in those characters that are expressed in proportional values. Figures are given also for a similar group of *artedi* from Lake Michigan.

Gill rakers on the first branchial arch:
- Erie, (41) 44–48 (53).[58]
- Michigan, (41) 46–50 (55).[59]
- Nipigon, (41) 46–49 (53).[60]

Lateral-line scales:
- Erie, (64) 71–81 (89).
- Michigan, (68) 77–87 (94).[59]
- Nipigon, (65) 71–76 (81).[60]

L/H:
- Erie, (3.9) 4.2–4.4 (4.7).
- Michigan, (4) 4.2–4.5 (4.6).
- Nipigon, (3.9) 4.1–4.3 (4.6).

H/E:
- Erie, (3.7) 3.9–4.1 (4.4).
- Michigan, (3.5) 3.7–4 (4.3).
- Nipigon, (3.5) 3.7–4 (4.1).

H/M:
- Erie, (2.5) 2.6–2.8 (3.1).
- Michigan, (2.4) 2.7–3 (3.1).
- Nipigon, (2.6) 2.7–2.8 (3).

H/S:
- Erie, (3.6) 3.7–4 (4.2).
- Michigan, (3.4) 3.6–3.9 (4.1).
- Nipigon, (3.6) 3.7–3.9 (4.2).

Pv/P:
- Erie, (1.6) 1.8–2 (2.2).
- Michigan, (1.6) 1.8–2.1 (2.5).
- Nipigon, (1.5) 1.6–1.8 (2).

Av/V:
- Erie, (1.3) 1.4–1.6 (1.8).
- Michigan, (1.3) 1.5–1.7 (2).
- Nipigon, (1.3) 1.5–1.6 (1.7).

L/D:
- Erie, (2.8) 3.6–4 (4.3).
- Michigan, (4.1) 4.4–5 (5.8).
- Nipigon, (3.8) 4.1–4.6 (5).

The figures show that the Nipigon race has, on the average, fewer lateral-line scales, less body depth, and longer pectoral fins than the *albus* form of Erie. The other differences can not be called significant in view of the disparity in the size of the specimens in the two groups. In respect to other characters given for the typical form under the general description the Nipigon form agrees rather closely, except that possibly the jaw tends to be a trifle longer and the fin rays tend to be slightly more numerous. Compared with small specimens of the *artedi* type of Michigan, which are probably very like those that might be found in Lake Erie, the Lake Nipigon race has still fewer lateral-line scales and still longer pectoral fins and probably also longer ventral fins than *albus*, but its body depth is greater on the average.

[58] The number of Erie fish examined to obtain the figures for gill rakers is 313, for lateral-line scales 750. The proportional figures are given for 125 individuals between the length limits of 128 and 224 millimeters, most of them more than 190 millimeters.

[59] Figures for Lake Michigan so marked are based on an examination of 391 specimens ranging in length from 127 to 367 millimeters. All figures for proportions are given for the specimens less than 225 millimeters in length, 150 in number.

[60] Figures for Lake Nipigon so designated are based on an examination of 84 specimens ranging in size from 138 to 253 millimeters. In other computations pertaining to Nipigon specimens 71 individuals ranging up to 225 millimeters are represented, most of them less than 190 millimeters long.

The color in life was not recorded. Fish observed swimming around the dock at Macdiarmid showed the characteristic blue green color on the back, and it is likely that the two forms are not very different in coloration. Preserved specimens from which all color has faded are only a trifle darker on the dorsal surface, and the fins also somewhat more pigmented. The anal and the ventrals frequently show more or less pigment.

No specimens were seen during the breeding season, and it is not known that pearl organs are developed. It is probable, however, that they are, and their development is not likely to differ from that exhibited by the species in the other lakes.

VARIATIONS

Racial variations.—So few specimens have been collected from any part of the lake that nothing can be said about the development of local races. No tendencies to vary in a definite direction are indicated by any of the specimens that I have seen.

Size variations.—Only 13 individuals 225 millimeters or more in length have been collected, and none of these are more than 253 millimeters long, so that it is not possible to form two contrasting size groups. The meager data given in Tables 8 to 11, where the specimens of 225 millimeters or more in length are compared in several characters with the group of smaller individuals, and Table 76, in which two specimens of less than 200 millimeters are compared extensively with eight of more than that limit, do not indicate any changes with growth, unless it be that the eye becomes relatively smaller. Specimens usually are sexually mature at 165 millimeters and occasionally even at 140.

COMPARISONS

In external characters *artedi* is very like *nipigon.* Apparently it does not grow so large as this form, which often is found over 300 millimeters in length, as compared with the largest collected *artedi* at 253 millimeters. The most trenchant difference between the two species, however, is the number of gill rakers on the first branchial arch, which in *artedi* are not known to number more than 53, while in *nipigon* no specimens are known with less than 54. The eye in *artedi* appears also to average distinctly larger. There are no specimens with a higher value for H/E than 4.1, and only two specimens of *nipigon* with a lower value than 4.1. The *artedi,* however, are on the average much smaller than the *nipigon,* and in specimens of comparable size the differences probably would not be so well marked. The maxillary, snout, and paired fins also average shorter in *artedi,* and the body has much less depth. No collected specimens of *artedi* have a value for L/D less than 3.8, while 66 per cent of the tullibees have a value less than 3.8. These characters may be compared better by consulting Tables 76 and 80, in which 10 specimens of each species are analyzed in detail. The fins of *artedi,* especially the paired fins and the anal, show less pigment than in *nipigon,* in which form almost all are invariably and often considerably pigmented. Another valuable criterion for separating the species is the state of the sex organs. No specimen of *nipigon* has been found to be sexually mature under 250 millimeters in length, while *artedi* usually is mature at 165 millimeters or less.

A discussion of the differences between *artedi* and the other species of Leucichthys in the lake is given under the heading "Comparisons" in the accounts of these species.

GEOGRAPHICAL DISTRIBUTION

As in the other lakes, the herring of Lake Nipigon move in schools, and these schools are seen often off the dock at Macdiarmid. No commercial fishing operations whatever are conducted on Lake Nipigon for herring, or for any other species of Leucichthys, for that matter, and all that is known about the occurrence and distribution of the species in the lake has been learned from the employment of small-meshed nets by the University of Toronto investigators and me. The data from these nets indicate that herring occur throughout the lake at suitable depths. The locations in the lake from which specimens have been obtained are given in Table 75, and they are platted in Figure 2.

SEASONAL MOVEMENTS

Nothing is known about seasonal movements, as the University of Toronto investigators always have been engaged only in summer and have made no particular efforts to study the habits of herring. Sets of nets were made during the summer, however, at all depths to 65 fathoms, and it is interesting to note in Table 75 that between July 16 and September 11 in several seasons no numbers of individuals were taken in the netting at depths of more than 15 fathoms. The deepest set that showed herring was made by me off Macdiarmid in 30 fathoms on July 28, 1922, and only one individual was present among dozens of other Leucichthys (record 1). It is probable, then, that the species at no time frequents great depths and during the summer either traverses the surface waters of the open lake, as in Lake Superior, or sinks to depths of 15 fathoms or less. The schools, in that case, without doubt come ashore in fall to spawn.

BREEDING HABITS

Nothing is known of the time of spawning, but none of the individuals collected as late as September showed well-developed sex organs, and the two specimens taken on October 26, 1922 (record 21), were not yet ripe. The spawning season is probably in late November, as in Lake Superior, and the spawning grounds are probably in shallow water, as is usual for the species.

Leucichthys artedi artedi and artedi albus of Lake Ontario

The *artedi* of Ontario are variable, as in Lake Erie, and the same two types are represented, namely the terete blueback and the deep, more compressed form. The latter, however, is usually always elliptical in side view in Lake Ontario. The difference between the two types in Lake Ontario is largely in this aforementioned body shape and color, and as these characters, excepting the length-depth ratio (L/D), do not lend themselves to numerical expression, the characters that can be expressed thus may be combined for both types for comparison with the combined types for Lake Erie. The races may be compared better and in more detail in Tables 67 and 78, where 20 large *albus* and 10 large *artedi* for Lake Erie and 10 large specimens nearest the *artedi* type and 10 nearest the *albus* type for Lake Ontario are analyzed. The

two types of Ontario are discussed further under the section "Variations." The various characters of systematic value are compared below:

Gill rakers on the first branchial arch:
- Erie, (41) 44–48 (53).[61]
- Ontario, (41) 46–50 (54).[62]

Scales in the lateral line:
- Erie, (64) 71–81 (89).
- Ontario, (66) 73–82 (89).

L/H:
- Erie, (4.1) 4.3–4.7 (5.2).
- Ontario, (3.7) 4.3–4.7 (5).

H/E:
- Erie, (3.8) 4.2–4.5 (4.9).
- Ontario, (3.9) 4.1–4.4 (4.9).

H/M:
- Erie, (2.5) 2.7–2.9 (3.3).
- Ontario, (2.5) 2.7–2.9 (3.3).

H/S:
- Erie, (3.6) 3.8–4 (4.5).
- Ontario, (3.4) 3.7–4 (4.5).

Pv/P:
- Erie, (1.6) 1.9–2.1 (2.5).
- Ontario, (1.7) 1.9–2.1 (2.5).

Av/V:
- Erie, (1.4) 1.6–1.8 (2.1).
- Ontario, (1.3) 1.5–1.8 (2).

L/D:
- Erie, (2.8) 3.3–3.7 (4.8).
- Ontario, (2.9) 3.6–4.3 (5).

It appears from the foregoing that the composite collections have similar characters. Only the body-depth ratio appears to be different in the two forms, Erie fish averaging deeper.

The color in life is, in general, like that of the Erie form. The deep-water individuals average paler than those from shallow water, even though they may, in other respects, be exactly like them, and often show pinkish bases to the fins, especially the abdominal ones. It is possible that the presence of the pinkish color is due to congestion caused by the constriction of the net threads. The shoal form is colored about like the Erie blueback.

The males and at least some females develop pearl organs in the breeding season. Specimens collected off Bronte, Ontario, on November 23, 1917, show pearls that differ in development in no material way from those described for the typical form.

VARIATIONS

Racial variations.—There are two more or less distinct types of herring in Lake Ontario, as in Lake Erie. While in Lake Erie the slender blue-backed type is comparatively rare and the herring population is constituted primarily of deep, somewhat compressed individuals, the reverse is the case in Lake Ontario, except that the deep form is much more abundant, relatively, than the Erie blueback. The most typical specimens of this deep-water variety have been taken on the spawning grounds of the west shore of the lake (records 1 and 2). The most typical specimens of the shoal type are those from Wellers Bay and South Bay (records 5 and 7). The rest are more or less intermediate. This deep-water form has a deeper, somewhat more compressed body and averages paler in color than the herring from the shoals, but a comparison of other characters shows no important differences. Its appearance, therefore, is quite like that of the typical *albus* of Erie. The other herring of the lake are about

[61] These figures for Lake Erie are based on an examination of 313 specimens ranging in length from 128 to 402 millimeters. Those for scales are based on 750 specimens of the same size range, but figures for proportions are based only on 163 of the specimens 225 millimeters or more long.

[62] These figures for Lake Ontario are based on an examination of 254 specimens ranging in length from 155 to 366 millimeters. Those for scales are given for 266 specimens of the same size range. All other figures are based on an examination of 205 individuals ranging in length from 225 to 366 millimeters.

like the Erie bluebacks, except that, on the average, they probably have somewhat longer paired fins.

Size variations.—Very few small herring have been examined, and these are from varied situations in the lake, so that nothing can be stated conclusively about the changes with growth; but a comparison of the characters in Tables 8 to 11 for large and small individuals indicates, as is to be expected, that the head and eye are larger, relatively, and the paired fins longer in the small individuals. Other data indicate that the maxillary and snout are relatively somewhat longer in small fish and the body depth less. Ranges of values for the characters follow:

L/H:
- Large fish, (3.7) 4.3–4.7 (5).
- Small fish, (3.9) 4.1–4.4 (4.6).

H/E:
- Large fish, (3.9) 4.1–4.4 (4.9).
- Small fish, (3.8) 4–4.2 (4.4).

H/M:
- Large fish, (2.5) 2.7–2.9 (3.3).
- Small fish, (2.5) 2.6–2.8 (3).

H/S:
- Large fish, (3.4) 3.7–4 (4.5).
- Small fish, (3.6) 3.8–3.9 (4.2).

Pv/P:
- Large fish, (1.7) 1.9–2.1 (2.5).
- Small fish, (1.6) 1.8–2 (2.2).

Av/V:
- Large fish, (1.3) 1.5–1.8 (2).
- Small fish, (1.2) 1.4–1.6 (1.7).

L/D:
- Large fish, (2.9) 3.6–4.3 (5).
- Small fish, (3.4) 3.7–4.4 (4.8).

All the specimens collected, even the smallest one of 155 millimeters, were sexually mature.

COMPARISONS

A discussion of the differences between *artedi* and the other species of Leucichthys, except *nigripinnis*, occurring in Lake Ontario is given under the heading "Comparisons" in the accounts of these species.

From *nigripinnis* the species probably was distinguished chiefly by the more elliptical outline of the body, as seen from the side, by its firmer and drier flesh, and by its shorter maxillary, snout, and paired fins. *Nigripinnis* spawned a month later, also.

GEOGRAPHICAL DISTRIBUTION

Herring occur throughout the lake, though only in a few localities are they abundant enough to be commercially important. The largest catches are made in the deep water at the western end of the lake and in shallow water at the east end, from the Bay of Quinte region to as far west as Sodus Point on the New York shore. They occur in the eastern waters in relatively deep water during the summer and are fished for to some extent. Specimens have been collected at many ports. The data for these are given in Table 77 and are shown platted on the chart in Figure 7.

METHODS OF CAPTURE

Virtually all of the herring in the Canadian waters are taken with gill nets. These nets have been of 2½-inch mesh in the western waters and of 3-inch mesh elsewhere. In New York waters gill nets, which must be of 3-inch mesh, are employed widely, exclusively when the fish are off the shore; but when the fish come ashore to spawn, especially in Chaumont Bay and Sodus Bay, they are taken largely by trap nets. These nets may be floated even at that season.

SEASONAL MOVEMENTS

As in the other lakes, the schools of herring in Lake Ontario move inshore in spring and fall. There is no evidence to indicate that they remain inshore during the winter, and on account of the violence of currents in the lake to depths of 30 fathoms and more, even in summer, it is not likely that any numbers of herring brave the turbulent conditions that must obtain often on the shores in winter.

Data on occurrence in the herring nets in spring and fall.—In the western waters of the lake, off the ports from Niagara, N. Y., to Bronte, Ontario, and also somewhat farther eastward, the principal herring is the deep-water form. These fish, according to the testimony of many fishermen, replaced the "cisco" (probably *Leucichthys hoyi* and *nigripinnis*) which supported a fishery since about 1860. These ciscoes declined in abundance toward the end of the century, and the fishermen are of the opinion that the territory formerly occupied by them has been taken over by the blue-backed or shore herring. The deep-water fish are little different from their shore relatives except that they are fatter (see p. 508), and the fishermen may be right in their postulate that they are descendants from them. At any rate, shore herring are not common along the west end, but some do occur along the shores and in Burlington Bay in October and November, and some few again in April and May. The deep-water form is now taken most abundantly in fall, when it settles to the bottom to spawn. The schools move within a few miles of shore in 15 to 30 fathoms of water about October 1 and are densest in November. The catch usually drops off abruptly after early December, but sometimes enough fish remain on the grounds to permit the continuation of fishing operations through the winter.

Latterly the herring catches have dropped off and winter fishing has been discontinued for the most part. These fish are not taken in summer. The fishermen have suggested that they swim off the bottom at that season, and, as will be seen later, this explanation is probably sound. At Brighton, Ontario, according to Harry and W. A. Quick, the herring come onto the shoals around October 1 and by November 1 enter the Wellers and Presque Isle Bays and also the Bay of Quinte. They are said to remain until the bays freeze. In the spring they are again present on the shoals during the month of May but do not enter the bays at this time. At Sandy Pond, N. Y., according to Perry Bartlett, the fish come onto the lake's shores in early October and enter the Sandy Ponds in early November. They return to the lake after spawning, in early December, and do not come ashore again in spring. At Sodus Point, N. Y., Hurd Doville says the herring schools come ashore around October 1 and move into Sodus Bay and onto the beaches about November 1. The fish leave the bay abruptly after spawning, and Mr. Doville says that from 1914 to 1920, seven years for which he has records, the date of departure was between December 3 and 5, regardless of weather conditions. A few enter the bay again in spring when the ice leaves, but they are more numerous on the beaches in water as shallow as 20 feet. They remain only about three weeks and are gone by the middle of May into deep water, where they may be taken occasionally during July. In and about Chaumont Bay many herring come ashore to spawn, as in Sodus Bay. At Wilson, N. Y., herring formerly were at 15 to 20 fathoms in October and November, according to Timothy Wilson, but commercial fishing has been abandoned practically at this port in the last 25 years, and now very few are taken.

Data on summer occurrence.—The herring are not followed in the spring because other fish can be taken in greater quantity at that time, and the only data we have on the location of the herring schools in summer are from the east end of the lake. On Lake Ontario few fishermen claim ever to have seen herring swimming at the surface in the open lake, a phenomenon not uncommonly witnessed in the upper lakes where the water is cooler, and the belief is held generally that these fish sink to the bottom and remain there during the warm months. On the eastern New York shores, off Sandy Pond, Selkirk, and Port Ontario, within the last 10 years, and within the last two years off Oswego, the fishermen have taken to herring fishing when the whitefish fell off or they employed herring nets along with the whitefish nets. The herring are found, according to Perry Bartlett, Garry Tifft, and Jacob Fickeis, fishermen at the aforementioned ports, from May, when the nets are put in, to about September in 20 to 30 fathoms of water and even deeper. The lifts during July and August are best, and the herring run large, as nets of 3-inch mesh are used exclusively. Lifts examined by me off Selkirk on July 11, 1921, in about 30 fathoms, and off Sandy Pond on August 24, 1923, at about the same depth, showed herring to occur in these waters in abundance. A lift witnessed on September 1, 1923, off Oswego in 30 fathoms had few fish, although Mr. Fickeis said that in August the lifts had been so heavy that it had been impossible to dispose of the fish caught. About September the lifts drop off in the deep water, and the fish apparently rise above the bottom at that season. Mr. Fickeis used a number of deep bull nets employed on Lake Erie, which fish up to 25 feet above the bottom, and on September 1 it was only in these nets that any quantity of herring was taken.

The occurrence of herring in abundance at depths of 30 fathoms is unknown in any other lake except Erie, where it is known that they occupy the maximum depths of 30 to 35 fathoms in December; but this situation may be accounted for by the peculiar limnological conditions in Lake Ontario. In none of the other lakes are nets in danger during a blow in 30 fathoms, and except in the colder months such nets usually would show no influence of the wind. In Lake Ontario, on the other hand, summer breezes may demolish netting by the induced currents at depths of 30 fathoms. Nets lifted on August 24, 1923, off Sandy Pond from 30 fathoms, after one of the breezes usually experienced in late summer, were practically destroyed by the débris that the currents swept into them. Tree trunks 10 feet long and 4 inches and more in diameter were among the detritus. The force of the currents is greatest in the shallow water and no doubt diminishes toward the deeper water, so that to escape these unsettled conditions the herring may seek refuge in water deeper than in the other lakes. Unfortunately, no temperature readings were taken anywhere on Lake Ontario, so that it is not known whether temperature is a factor in this depth migration of the herring. The maximum depth to which individuals migrate is not known, but a few specimens were taken in 3 to 3½ inch gill nets lifted on August 30, 1923, off Sandy Pond, N. Y., from 60 fathoms, and on September 4, 1923, off Oswego, N. Y., from 70 to 75 fathoms (records 9 and 12).

The records of the fishermen covering commercial-fishing operations for the herring thus show that they begin to move ashore in commercial quantities in early October and that they continue on these grounds until the ice forms in early December. The deep-water form at the western end of the lake comes no nearer shore than 15

to 30 fathoms in the fall, but elsewhere the migration is onto the shoals and into the bays. None of the fish are known to remain in shallow water during the winter, and only at a few ports are they known to return to shallow water again in the spring, though it is probable that the onshore movement at that season is general. At Bronte and Brighton, Ontario, and at Sodus Point, N. Y., some fish are present on the shoals in May. In summer the herring at the west end are said to swim off the bottom and are not fished for, while those at the east end congregate at depths of 20 to 30 fathoms and even to 75 fathoms from May to September, where they are taken at times when market conditions are favorable or when no other species of fish is to be had in marketable quantities. There are no fishing operations of any consequence on the American shore except at the eastern end of the lake, and on the Canadian shore fish other than herring occupy the attention of the fishermen except in the fall.

BREEDING HABITS

The inshore migration in the fall is for the purpose of spawning. Except for the deep-water form at the western end of the lake, which spawns at depths of 15 to 30 fathoms presumably on clay bottom, the herring elsewhere spawn on the shoals and in the bays as shallow as 10 feet. The bottom selected is sand, as a rule, though in the bays pond conditions obtain and the bottom is usually carpeted with the last previous summer's growth of Myriaphyllum, Ceratophyllum, and Utricularia. The time of spawning is usually from the middle to the last of November, and the season, according to the fishermen, lasts about 10 days.

Hurd Doville, who has fished herring in Sodus Bay for the last 15 years, says that the larger males appear first on the grounds, and after spawning is nearly finished there is a run of small males. The fish are caught best in gill nets when spawning, and Perry Bartlett says usually they are taken at the bottom of the netting at this time, which indicates that they spawn near the ground. After spawning, the fish leave abruptly. It is not known definitely when the young, which are hatched in the bays, enter the lake.

VALUE AS FOOD

The western deep-water herring are of the same quality as those of Lake Erie and often are prepared smoked on account of their oily flesh. Other herring are less fat and are not esteemed generally, but there is some demand for them locally, and at certain seasons they can be disposed of to advantage in the New York markets.

RELATIVE ABUNDANCE

Herring have been fished for on Lake Ontario for more than 50 years. In the western waters there has been a decrease in their numbers, according to statistics and according to the testimony of fishermen. The herring fisheries now exploited in the Bay of Quinte region and in the eastern American waters are of relatively recent origin, and in the last decade they have become of great importance in the fisheries of the lake. Perry Bartlett is of the opinion that there has been a decline in the number of herring at Sandy Pond. Hurd Doville, who has fished them at Sodus Bay for the last 15 years, says the runs have not been good for the last five falls.

George Jones, a fisherman at Sodus, says that at one time the herring disappeared entirely for a number of years from Sodus and returned later in abundance, and the fishermen are now expecting them to disappear once more.

LEUCICHTHYS NIPIGON Koelz

Leucichthys nipigon, Koelz, 1925, pp. 1–3, Lake Nipigon; Dymond, 1926, pp. 61–62, Pl. II, Lake Nipigon.

This species is not known to occur in any of the Great Lakes proper, but specimens have been seen from Lake Winnipeg and from Black Sturgeon Lake near Lake Nipigon. (Fig. 28.)

The type is a male specimen (catalogue No. 87092, U. S. National Museum) 282 millimeters in length to the base of the caudal, collected in Lake Nipigon off Macdiarmid at a depth of 30 fathoms on July 28, 1922.

The fish grows to a larger size than any species of Leucichthys seen from the Great Lakes, though it is possible that when these waters were virgin, as Lake Nipigon now is, some individuals of the larger species in the Great Lakes equaled those of this form in this respect. The largest specimen I have seen is from the University of Toronto collection and measures 447 millimeters. Examples longer than 300 millimeters are common. The flesh appears to be dry, like that of lake herring (*artedi*), and the shape of the body is very close to that of the deep-bodied, compressed, tullibee type of this form; namely, it is elliptical in outline as seen from the side. In the case of the largest examples, however, the anterior dorsal contour may rise rather sharply at the occiput over two-thirds its course and then continue to the dorsal insertion with little further elevation. The body is relatively very deep, especially in the larger individuals, and is moderately compressed; the depth is contained in the total length 3.5 [(3) 3.3–3.8 (4.1)] [63] times. The body width has been so altered by artificial compression that in the preserved material at hand it does not appear worth while to record the proportional relations of this character. The head is moderately elongated and is contained 4 [(3.8) 3.9–4.1 (4.5)] times in the total length. Its dorsal profile is nearly straight usually. The premaxillaries are directed forward and make an angle of about 55° with the horizontal axis of the head. The snout is contained 3.8 [(3.3) 3.5–3.8 (4)] times in the head length; the eye 4.4 [(3.8) 4.4–4.6 (5.2)] times; and the maxillary 2.7 [(2.5–2.7 (3.1)] times. The mandible in the type is equal in length to the upper jaw, but in the paratypes it is often somewhat longer or shorter. The gill rakers on the first branchial arch number 19+37 [19–21 (24)+35–37 (43)=(54) 56–59 (66)]. The scales in the lateral lines are 75 [(68) 72–77 (82)] in number. Scale rows [64] around the body just in front of the dorsal and ventrals number 42 [(41) 43–45]; just in front of the adipose and anus, 33 [(32) 33–34 (35)]; around the caudal peduncle at its commencement, 23 [(23) 24–25 (27)]. The pectorals are very long, being contained in the distance from their insertion to the ventrals 1.8 [(1.4) 1.5–1.7 (1.9)] times. The ventrals also are long. Their length divided into the distance from their origin to the insertion of the anal equals 1.6 [(1.3) 1.4–1.5 (1.7)]. There are 10 [10–11] [64] dorsal rays,

[63] These and unmarked figures are based on measurements of 43 paratypes ranging in length from 220 to 447 millimeters.

[64] Ten specimens.

12 [11–12 (13)] [64] anal rays, 12 [12 (13)] [64] ventral rays, 15 [(15) 16–17 (18)] [64] pectoral rays, and 8 [8–9 (10)] [64] branchiostegal rays.

The appearance of the species in life is silvery, with the underlying tints of green and the superficial iridescence that characterize all the Great Lakes forms of Leucichthys. Preserved specimens show moderate pigmentation on the back but heavier pigment on the cranium. The prenarial region is often nearly black, as is the tip of the mandible. The preorbital area and the maxillary also are always pigmented. The dorsal and caudal fins are widely margined with smoky, the hue being deepest on the short rays of the caudal. The paired fins and the anal always show more or less of pigment.

No breeding fish have been seen, and it is not known that pearl organs are developed in the breeding season, but it is likely that they are.

VARIATIONS

Racial variations.—Very few specimens have been examined, and it is not possible to state from the material at hand whether there are races within the species.

Size variations.—Sixteen of the forty-four specimens are less than 300 millimeters in length. A comparison of these with the larger fish indicates that the head, eye, maxillary, and paired fins become proportionally smaller with growth and the body depth increases proportionally. The figures follow:

L/H:
- Large fish, (3.9) 4–4.1 (4.5).
- Small fish, (3.8) 3.9–4 (4.1).

H/E:
- Large fish, (4.4) 4.6–4.8 (5.2).
- Small fish, (3.8) 4.2–4.4 (4.5).

H/S:
- Large fish, (3.3) 3.5–3.8 (4).
- Small fish, (3.5) 3.7–3.8 (4).

H/M:
- Large fish, (2.5) 2.7–2.8 (3.1).
- Small fish, 2.5–2.8.

Pv/P:
- Large fish, (1.5) 1.7–1.8 (1.9).
- Small fish, (1.4) 1.5–1.6 (1.8).

Av/V:
- Large fish, 1.4–1.6 (1.7).
- Small fish, (1.2) 1.4–1.5 (1.6).

L/D:
- Large fish, (3) 3.3–3.6 (3.7).
- Small fish, (3.5) 3.8–4 (4.1).

All but one of the specimens under 300 millimeters have been found sexually immature.

COMPARISONS

A discussion of the differences between *nipigon* and the other species of Leucichthys occurring in Lake Nipigon is given under the heading "Comparisons" in the accounts of these species.

GEOGRAPHICAL DISTRIBUTION

The data from my nets and those of the University of Toronto investigators set during the summers of 1921, 1922, 1923, and 1924 are given in Table 79 and platted on the lake chart in Figure 2 and indicate that this species is found throughout Lake Nipigon.

BATHYMETRIC DISTRIBUTION

Very little is known about the depth preferences of *nipigon*. The data that we have are obtained, for the most part, from the use of nets that were of too large

[64] Ten specimens.

mesh to gill any but extreme examples—namely, the 4½-inch whitefish nets. Some nets of 2½ and 2¾ inch mesh were set by me on July 26, 1922, off the source of the Nipigon River in 10 to 15 fathoms (record 10) and took 11 individuals along with 129 other Leucichthys, and a set made on July 28, 1922, off Macdiarmid in 30 fathoms (record 1) took only 3 out of 251. The same nets set on July 28, 1922, off Livingston Point in 56 fathoms took no individuals of the species. What data we have, therefore, indicate that the species is found in shallow water during the summer, at least. Dymond (1926) also suggests that it is a shallow-water form.

BREEDING HABITS

Nothing is known about the breeding habits of the species. None of the specimens taken from July to October showed sexual glands either ripe or recently spent, so that the spawning season must fall later than October and earlier than July.

Genus COREGONUS Linnaeus

The Great Lakes fish of the genus are relatively large. They are usually immature under 2 pounds and attain a weight of more than 20 pounds. The body is compressed laterally; its width is equal to about 50 per cent of its depth. The premaxillaries are wider (dorsal-ventral measurement) than long and retrorse in position.

FIG. 27.—Openings of a nostril in Prosopium (A) and in Coregonus (b)

The two openings of each nostril are separated by two flaps. (Fig. 27.) The exposed area of the scales of the lateral line is not conspicuously smaller than that of those of the adjacent rows. The gill rakers on the first branchial arch are usually less than 32 and more than 20. Vestigial teeth are usually present on the premaxillaries, palatines, mandible, and tongue. The prefrontal bone is moderately developed, more than in Prosopium but less than in Leucichthys. The carina of the frontals extends to the frontal-parietal suture.

COREGONUS CLUPEAFORMIS Mitchill

THE WHITEFISH (FIG. 29)

Salmo clupeaformis Mitchill, 1818, p. 321, Sault Ste. Marie.
Coregonus clupeiformis Evermann and Smith, 1896, pp. 297–301, pl. 17, Great Lakes.
Coregonus clupeaformis Jordan and Evermann, 1911, pp. 35–37, fig. 19, Pl. VI, Great Lakes, except Erie; Dymond, 1926, pp. 55–57, Lake Nipigon.
Salmo otsego Clinton, 1822, pp. 1–6, fig., Otsego Lake.
Coregonus labradoricus Richardson, Evermann and Smith, 1896, pp. 302–305, pl. 19, Great Lakes; probably also Richardson, 1836, Labrador.
Coregonus sapidissimus Agassiz, 1850, pp. 344–348, Lake Superior.
Coregonus latior Agassiz, 1850, pp. 348–351, Lake Superior.
Coregonus neo-Hantoniensis Prescott, 1851, p. 343, Lake Winnepesaukee.
Coregonus albus LeSueur, Jordan and Evermann, 1911, pp. 37–38, Pl. VI, Lakes Erie and St. Clair; not of LeSueur, 1818.

The whitefish was described originally from a specimen taken in St. Marys River below the falls. The type is not known to exist.

The whitefish is distributed generally throughout the Great Lakes. It is the largest and most valuable of the coregonids. The maximum size attained varies with the locality, but from the most favorable areas individuals have been reported weighing 26 pounds or more. Such large fish are now rare everywhere. In most of the lakes the largest fish now caught weigh 8 or 10 pounds, and but few examples so large are obtained annually. The species inhabits by preference the shallower water and spawns in late fall. In all of the bodies of water except Erie and Ontario the whitefish races are quite similar in appearance. Those from Lakes Erie and Ontario tend to have proportionally deeper bodies, and the Erie race is distinguished further by having, on the average, fewer lateral-line scales and probably fewer pectoral rays and scale rows.

A description of the Lake Michigan form is given as typical for the sake of uniformity of arrangement of the various sections of the text, most of the other types of Great Lakes coregonids having originated in that lake. The whitefish of Lake Huron, which the St. Marys River fish probably most nearly resembles, is, moreover, virtually identical in its characters with the whitefish of Lake Michigan.

Coregonus clupeaformis of Lake Michigan

The body is compressed, fusiform, and rather elongate, with its greatest depth through a point just in front of the dorsal. This dimension varies considerably, but for specimens under 40 centimeters in length it is contained (3.3) 3.9–4.3 (4.8) [65] times in the total length. Larger fish, especially the females, certainly would average deeper. From the occiput the dorsal profile curves upward to the insertion of the dorsal fin. In specimens up to about 2½ pounds in weight (about 420 millimeters long) the rise of this curve is even and gradual, but in larger specimens its cranial half rises more rapidly than the caudal, while the caudal half continues with little further elevation. Thus, the predorsal profile becomes more convex in large fish, wherefore the fishermen often call them "bowbacks." The base of the dorsal usually is somewhat inclined caudally toward the lateral line. It often lies below the general level of the back. The contour line between the dorsal and the adipose is nearly straight. The ventral profile descends in a gentle curve from the tip of the mandible to the ventrals and then rises in a sharper curve to the caudal peduncle. The head, viewed from the side, is relatively small and of little depth and varies in shape from obtuse triangular to acute, according to the shape of the snout. Its length is contained (4.2) 4.4–4.8 (5.3) times in the length of the fish. Its dorsal profile varies from a nearly straight line to a faint double curve. In the latter case the curve is convex from the tip of the snout to a point above the caudal margin of the eye and concave from the latter point to the occiput. The convexity of the anterior dorsal contour is often very pronounced in large individuals. The ventral

[65] These and succeeding figures (unless otherwise marked) are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. All but two of these are less than 2 pounds in weight, such specimens having been selected for reasons of economy and convenience. In the proportional values given for these specimens, therefore, it should be borne in mind that larger specimens may regularly have values, particularly for L/H and H/E, that will not fit in the usual range of these values given for the smaller fish, and which may even fall outside the extremes here recorded. The changes accompanying growth are considered in a succeeding paragraph.

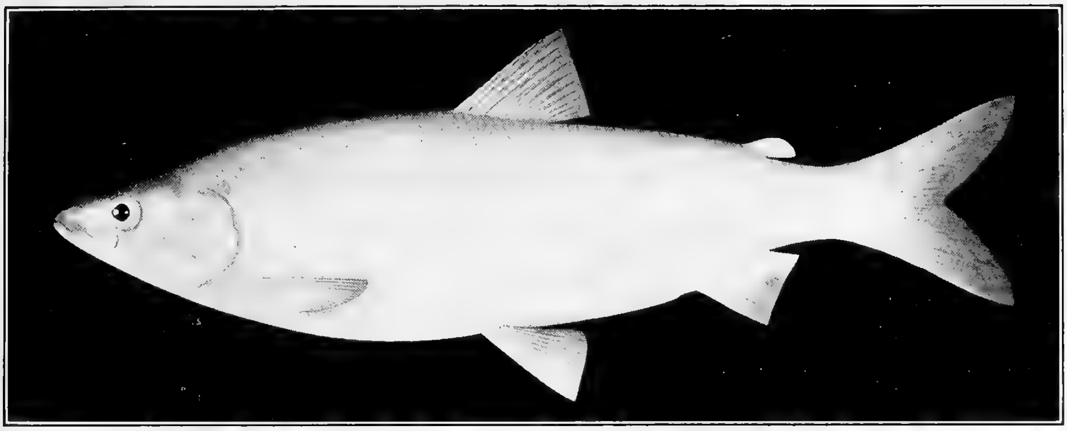

Fig. 28.—*Leucichthys nipigon* Koelz, the tullibee. Male (type), 282 millimeters long, taken in Lake Nipigon in Orient Bay in 30 fathoms on July 28, 1922

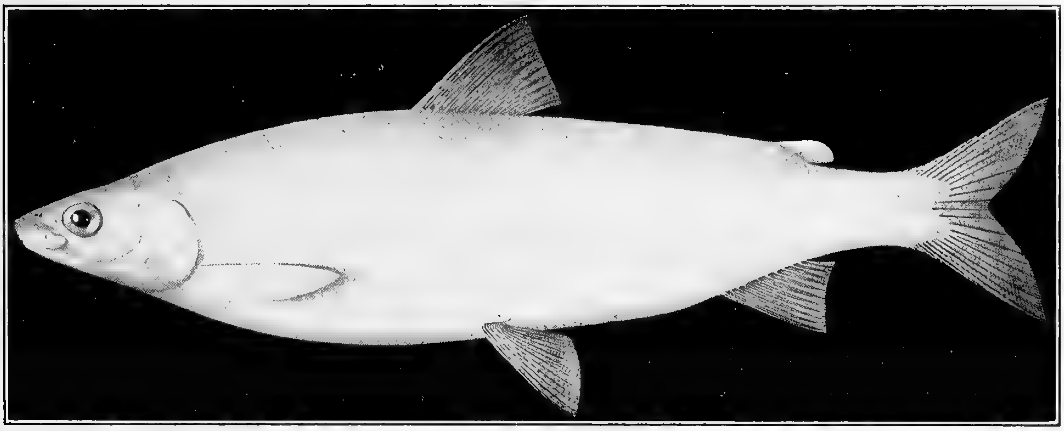

Fig. 29.—*Coregonus clupeaformis* Mitchill, the whitefish. Immature fish, 305 millimeters long, taken in Lake Huron in Thunder Bay in 8 to 10 fathoms on September 24, 1917

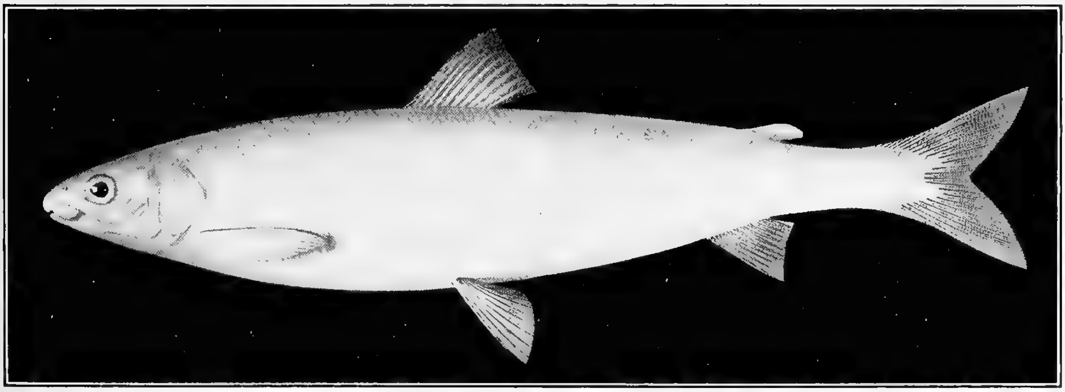

Fig. 30.—*Prosopium quadrilaterale* Richardson, the pilot. Female, 275 millimeters long, taken in Lake Huron off the Duck Islands in 2 fathoms on October 22, 1919

profile of the head is straight. The cheeks are nearly flat, converging slightly in a downward direction. The dorsal surface is triangular. The sides of the triangle converge gradually from its base at the occiput, so that the snout is not sharply compressed and its apex is rounded in front by the retrorse premaxillaries. The width of the head through the nares is about 22 to 23 per cent of its length. A heavy median keel, becoming heaviest in the center of its course, runs from the occiput to the premaxillaries; as a result, the cranial surface is distinctly convex from side to side. The ventral surface is like the dorsal, but nearly flat from side to side. The branchiostegal membrane is supported by (8) 9–10 rays. Their proximal margins run in a nearly smooth line with the outer lateral margin of the longest ray, so that the entire figure is saber shaped. The borders of the isthmus are only slightly convergent and join the mandible without uniting. The mandible is not conspicuously compressed. The premaxillaries are wider (dorso-ventral measurement) than long and are retrorse in position, making the mouth inferior. The extent of their backward slant determines the shape of the snout, which may be elongate and tapering or nearly truncate. Its length is contained in the head length (3.2) 3.4–3.7 (4.1) times and is nearly equal to the short maxillary, which is contained (3) 3.2–3.4 (3.8) times. The maxillary is always pigmented and seldom extends beyond the anterior edge of the pupil. The eye is relatively small, decreasing conspicuously in relative size with age, and is contained between 3.8 and 5 times in the head in the specimens examined. For specimens under 250 millimeters in length the value is usually 3.9–4.3; in specimens 250 to 350 millimeters long 4.4–4.8, and in larger fish more than 4.8. The pupil is roundish, with usually a conspicuous angle in front, from which characteristic the name Coregonus has been applied to such fishes. The gill rakers on the first branchial arch are (9) 10–11 (12) + (14) 16–17 (19) = (24) 26–28 (30).[66]

The scales in the lateral line number (74) 81–88 (93).[67] Scale rows [68] around the body just in front of the dorsal and ventrals number (46) 48–50 (52); in front of the adipose and anus, (36) 37–39 (40); around the caudal peduncle at its commencement, 25–27 (28). The length of the pectorals in contained (1.5) 1.7–2 (2.3) times in the distance from their origin to that of the ventrals. The ventral length is contained (1.3) 1.5–1.8 (2) times in the distance between their origin and that of the anal. The adipose is scaled often to one-third its extent and is variable in size. There are (10) 11 (12) [68] dorsal, ventral, and anal rays and (14) 15–16 (17) [68] pectoral rays. (See also fig. 12.)

The color in life has been recorded incompletely but is not different from that given under this heading for the Lake Superior form.

COLOR IN ALCOHOL

Most of the specimens preserved show the entire dorsal surface suffused with a more or less smoky, sometimes nearly black, hue, which diminishes in intensity to the lateral line and is absent below it, though pigment dots are present to the belly. The hue on the back is often darkest in front of the nares, descending onto the retrorse premaxillaries but usually stopping abruptly before reaching their

[66] One hundred and fifty-one specimens.
[67] One hundred and ninety-one specimens.
[68] Twenty specimens.

cutting edge. Pigment dots usually are grouped in bands around the free margins of the scales, the bands showing best below the lateral line where the dusky hue is absent. Above the lateral line and on the back there are often, especially in fish over 300 millimeters in length, one or two or more well-defined dots of pigment lying below each scale near the center of its exposed surface. There is no pigment on the belly. The sides of the head are pigmented throughout, most heavily in the preorbital area. The mandible is white. All fins are more or less smoky in color throughout, but the ventrals are usually darkest and the pectorals are possibly the palest. The fish caught off Port Washington, Milwaukee, and Michigan City show comparatively very little pigment. The back is not smoky, there are no bands around the free margins of the scales below the lateral line, and the abdominal fins are usually immaculate. These unpigmented fish are among the smallest specimens in the collection, and it is possible that pigmentation increases with age. Specimens equally small, however, and which show decided pigmentation, were taken in Grand Traverse Bay and around the South Manitou Island.

Pearl organs very likely are developed in the breeding season by sexually mature individuals, as in other lakes. Few specimens taken at that time have been examined, but it is probable that the development of the pearls is not different from that recorded for Lake Huron specimens.

VARIATIONS

Racial variations.—So few specimens have been collected from any one port that nothing can be said of race differentiation. No conspicuous features are exhibited by any of the fish collected from various localities, except that pointed out in the preceding paragraph, namely, that specimens south of the island region are less pigmented.

Size variations.—In Table 82, 10 specimens of various sizes are compared in detail. The collected specimens, divided into two size groups at 300 millimeters, show, like specimens of the table, that changes with growth evidently concern principally the relative size of the eye and to less extent that of the head.

GEOGRAPHICAL DISTRIBUTION

All records indicate that originally the whitefish occurred in abundance all along the shores of Lake Michigan and around the islands to the north. At present it has been so reduced in numbers that over most of the shore line it is commercially insignificant, and only in the northern sector of the lake is it still the object of special fisheries.

Specimens have been collected by me from several ports. Complete data for these are given in Table 81 and are platted on the chart in Figure 4.

METHODS OF CAPTURE

The principal methods of capturing whitefish are by means of pound nets and gill nets, the latter of about 4½-inch mesh. In the northern sector of the lake, north of a line drawn through Frankfort and Escanaba, both pound and gill nets are used, the latter chiefly on grounds in more than 10 fathoms and on the spawning

grounds in the spawning season. The catches during the spawning season are the heaviest, though at other seasons some quantities of whitefish are taken also; but the catches at other times are mixed with trout usually, and few fishermen could operate large-meshed gill nets if they were dependent on their catches of whitefish. Elsewhere in the lake there are now virtually no spawning grounds where numbers of whitefish can be gilled, and the whitefish thus taken are stragglers among the trout. The pound nets in the north depend for their success largely on the whitefish, though in Grand Traverse Bay rough fish, trout, etc., are a considerable factor in the profit of the fishermen. In other parts of the lake whitefish are chiefly of lesser importance because of their relative and absolute scarcity, and the pound nets are found profitable on account of the variety of fish taken and the better price that can be realized for the rough fish, due to proximity to the markets.

There is a notion widely current over the Great Lakes, based on the observation that gill nets do not take whitefish successfully in shallow water; that there are two kinds of whitefish, one of which will lead into the pound net and one that will gill only. An exposition of the principle on which the two types of apparatus depend for effectiveness affords an explanation for this belief. In Lake Michigan pound nets are fished only from shore to depths of about 50 feet, due to the expense of splicing the stakes used in holding the pots in deeper water. In Lake Huron nets sometimes are set to 90 feet, but for the most part all pounds everywhere on the Great Lakes are set within the first-named limit. In this shallow water, in the daytime at least, the netting is probably always visible to the fish, and the success of the pound net is due to the ability of the fish to detect the presence of the netting and to avoid it. Thus, when the fish encounter the leads of the pounds (which, by the way, are usually coarse enough to permit them to swim through them), some, at least, follow them and thus eventually find themselves in the pot, from which there is little chance of escape. If they did not sense the presence of the lead they would swim through it. The hordes of herring and other small fish that often fill the pots in summer and that remain in the pot until, on lifting, they are frightened through its meshes, illustrate the tendency of fish to keep free from contact with the netting. The success of the gill net, on the other hand, depends on its being unobserved by the fish, else the fish would follow along the meshes and not become gilled. Thus, the effectiveness of the gill nets probably declines directly as that of the pounds increases, and therefore gill nets are not successful in shallow water. Even in deeper water many of the gill-net fishermen believe that their lifts are heavier in the dark of the moon, while many pound netters expect better catches in the light of the moon. At times when gill nets make good catches in shallow water (namely, during the spawning season) the fish may enter the nets in the excitement of the mating act.

SEASONAL MOVEMENTS

Like the rest of the coregonids, the whitefish travel in schools, as shown by the fact that a gang of gill nets may catch all its whitefish in one or two boxes of nets, or by the fact that only one pound of half a dozen in the same neighborhood may take the fish. Many fishermen claim, also, to have seen these schools along the shores. The schools, it appears, are local in their habits and do not wander over

wide stretches of the lake. Evidence of this habit is derived from the facts that often the individuals from certain localities exhibit characteristics different from those possessed by individuals of a neighboring locality, and that when certain grounds are exhausted the abundance of the fish on grounds a few miles distant is undiminished. Earlier authors (Milner, 1874; Rathbun and Wakeham, 1897) made observations of the same sort and arrived at the same conclusion.

In the main, the movements of the fish are the same all over the lake. The schools move onshore and offshore like the other shallow-water coregonids, and the causes of the migrations are as little understood for the whitefish as they are for the others. The fishermen believe that temperature plays an important rôle in determining these movements, and the data presented appear to confirm this belief. Milner (1874a) mentions as a probable cause of the inshore movements in summer the presence of more oxygen in the shallower waters. Other writers have suggested that food may be more abundant on the shoals. Probably several factors work together to determine the movement of the fish, all of which are affected by the temperature.

I have collected data from the fishermen on the movements of the whitefish from most of the ports into which they are commonly brought. In Table 83 are given these data so far as they concern the pound nets.

Data from the pound nets.—The pound nets once set remain until pulled out at the end of the season or until blown out by storms, while gill nets are moved in and out at the option of the fishermen. Hence the data from the pounds show the occurrence of the fish at a given location during a fishing season, and the data for one location may be compared with those for another. The depth given in the third column is the depth in which the pot of the net is located. The leads of the pound run shoreward and often extend to the shore. Thus, the catch of any net presumably is a fraction of the fish that occur in the area between the shore and the pot.

The data in the table indicate that the fish do not enter the nets at the various points along the shore at the same season. In some areas they are on the shoals as soon as the nets are set in May (Traverse City, Beaver Island), and in others they may not appear until early July (South Manitou and Fox Islands), or not at all until September (Northport). In the extreme southern end of the lake they are most abundant in late May and early June (Michigan City), but at other points July seems to be the best month. Off Michigan City the schools are gone about the middle of June, off Traverse City about the first of July, and elsewhere about the first of August. Their return in the fall varies from early September to early October.

The catches of the pound nets are determined closely, all the fishermen agree, by the character of the weather. Meteorological conditions determine the time of their appearance on and disappearance from the shoals. Thus, the dates given in the table are only averages, and a variation of a week or more may be looked for from year to year, according as the summer is early or late, long or short. Even when the season is at its height, unfavorable water currents may drive the fish from the shoals temporarily. The currents, to be favorable, must be of moderate intensity and of low temperature.

Data from the gill nets.—Gill nets now are set for whitefish only in the northern part of the lake, but during most of the season the profits from these nets are deter-

mined as much by the trout that they take along with the whitefish. In the southern part of the lake the trout outnumber by far the whitefish, and as the trout here frequent deeper water than in the north, such few whitefish as still occur along the shores are not taken often in the gill nets. Out of most of the ports (Manistee, Frankfort, Northport, St. James, Traverse City) the nets find the whitefish in 20 to 30 fathoms when the ice leaves in April. By the middle of June the nets are, on an average, 10 fathoms shallower, and they are left at this depth for the summer. The gangs usually are moved in and out, according as the fish are found best at the deep or shallow ends of the gangs. During the last of August and early in September few whitefish are found anywhere, and it is not known whether they swim off the bottom at this season or avoid the nets. When the water begins to cool they are found again, and from late October until the spawning season is over they may be taken still nearer the beaches. In the fall the fish move in and out from day to day. Some whitefish are taken through the ice at depths of 10 to 20 fathoms.

The data from the two types of apparatus show the same habits for the whitefish. As soon as the ice leaves the fish are driven to the deepest water in which they ever are taken abundantly, namely, 20 to 30 fathoms. Individuals stray into deeper water occasionally during any season, and specimens have been caught in 60 fathoms or even deeper. One such is recorded from off Charlevoix, Mich., in Table 81. When the water begins to warm they approach the shores, and in July, in most localities, they are taken most abundantly in the pounds at depths of 16 to 65 feet (3 to 11 fathoms). In July and August the gill nets take them best at 10 to 20 fathoms. In fall they come ashore again and are taken best first by the pound nets and later, when they are spawning, by the gill nets. During the winter they probably remain near shore under the ice, but when the ice breaks they are driven to deeper water, possibly by the heavy shore currents at this time or in quest of food.

BREEDING HABITS

The time of spawning varies from year to year, but almost everywhere it begins sometime between November 15 and December 15. The season continues for about two weeks. The fishermen believe that the water must cool before the fish will spawn, and as some seasons are warmer than others, a variation in dates is to be expected. All the fish that gather on the various grounds do not spawn at the same time, in a given season, even in the same general area. Some of the interesting variations in the time of spawning for the vicinity of Grand Traverse Bay have been reported to me by John Greilick, of Traverse City, Mich., and B. Peter Anderson, of Northport, Mich., and for the northern islands by James and W. J. Gallagher and Dennis and Hugh Boyle, of St. James, Mich. Their observations have been confirmed by other fishermen. The spawning season of the whitefish in Grand Traverse Bay, at Mission Point, is two weeks later than at the Grand Traverse Lighthouse Point. Those at Tucker Point spawn still later than the Mission Point fish. Off Hog Island the whitefish may spawn in late October, while on Boulder Reef and off the Fox Islands the season will be a month later. The trout schools also are known to have varied spawning times in this area.

Spawning grounds are scattered all along the shores of the lake, but the most important are at the northern end of the lake on the reefs around the islands. Boulder

Reef and the Fox Island Reef are among the largest areas frequented by spawning whitefish. The bottom varies with the locality and may be gravel, honeycomb rock, or small stones. Sand or clay appear in general to be avoided now, though when the species was commoner some individuals may have been forced to spawn in such locations. The depth at which spawning takes place is from 1 to 10 fathoms, according to the fishermen. Earlier in the season some of these grounds are used as spawning places by the lake trout, but the whitefish do not spawn on all the trout-spawning grounds. Possibly some have unsuitable bottoms, though the fishermen do not know that there are differences between the trout grounds they visit and those that they do not.

Nothing definite is known of the spawning behavior of the whitefish, but several fishermen from different localities say that during the breeding season they have seen areas of the bottom on the spawning grounds cleaned of silt, such areas often being a square foot in extent. Whether these spaces actually are cleaned as sites for the eggs or whether they are the result of the body movement of the fish while spawning is not known. That the fish spawn by jumping out of the water, as has been described for pen fish, has been observed by no one anywhere on the lakes to my knowledge; and it is likely that these fish were trying only to escape from their pens, and, being ripe, their violent movements forced the eggs out.

The size of the whitefish at spawning varies with the locality. Among the largest spawning fish are said to be those of Jo Smiths Reef northwest of Hog Island, while those on the Fox Island Reef are among the smallest. It appears that the whitefish in Lake Michigan begin to spawn while still small, and most fishermen have seen individuals that were sexually mature at 1¼ to 1½ pounds in the round. Two male specimens weighing 10 and 13 ounces, taken off Algoma, Wis., and South Manitou Island late in July, were sexually mature. Scale examinations show, however, that these fish are in their fifth year and therefore are dwarfs. Study probably will show that maturity is a question of age rather than of size.

VALUE AS FOOD

The flesh of the whitefish brings a price, on the market, greater than that of any other lake fish except the sturgeon. Its value as food has been recognized fully since its existence in the lakes has been known.

ABUNDANCE

In consequence of its food value, the whitefish, in the earlier days, was sought for the markets with the aid of every device that human ingenuity could invent. At no season was the pursuit relented, and no fish were too small to be taken. The smallest, together with the herring and the sturgeon, often were carried out onto the beach because they were so numerous that they interfered with the capture of the larger whitefish. Though originally whitefish were found in incredible abundance all along the shores of the lakes (in fact, it is said that the species was the predominant one on the shoals), they could not endure long such drains on their numbers. Where for 1880 the Federal statistics show a production in Lake Michigan of over 12,000,000 pounds of whitefish, the catch for 1922 is given as a little over 1,500,000 pounds,

despite the great increase in quantity and effectiveness of the fishing apparatus and increase in value of the fish taken. It is noteworthy, also, that the areas that produced the whitefish of 1880 are not those that yielded the bulk of the 1922 catch. Many millions of fry have been planted in the lake since 1880 and the fish have been protected more carefully, but the effectiveness of propagation and protection has been reduced by the pollution of the lake from the industrial cities that have sprung up along its shores and by other abuses. It may be pointed out here that the success of propagation of the species in the Great Lakes has not yet been demonstrated. It is true that there has been reported from time to time in various areas increases in abundance, which have been ascribed to artificial propagation; but there may have been other causes for these phenomena, among which may be mentioned the indisputable decrease of suckers (which possibly compete with the whitefish, as Clemens has found in Lake Nipigon) and of predatory species that may feed on the young. Certainly if the increase could be credited positively to propagation acitvities, it is a result of chance and not of careful and intelligent disposition of the fry. Hatching methods reached the climax of perfection many years ago, and despite the fact that it has been apparent that by far the greatest percentage of the fry planted never were heard from, no investigations have been made to determine why plants were not more successful. Almost nothing is known of the life of the whitefish up to the time it is taken in the commercial nets.

Coregonus clupeaformis of Lake Huron

The Lake Huron whitefish has the general appearance of the Michigan form. The systematic characters capable of numerical expression are given below:

Gill rakers on the first branchial arch:
- Michigan, (24) 26–28 (30).[69]
- Huron, (24) 26–28 (31).[70]

Lateral-line scales:
- Michigan, (74) 81–88 (93).
- Huron, (73) 80–88 (91).

L/H:
- Michigan, (4.2) 4.4–4.8 (5.3).
- Huron, (4) 4.5–5 (5.1).

H/E:
- Michigan, (3.8) 4–4.4 (4.8).
- Huron, (3.8) 4.1–4.5 (4.6).

H/M:
- Michigan, (3) 3.2–3.4 (3.8).
- Huron, (2.9) 3.1–3.5 (3.8).

H/S:
- Michigan, (3.2) 3.4–3.7 (4.1).
- Huron, (3.2) 3.4–4 (4.4).

Pv/P:
- Michigan, (1.5) 1.7–2 (2.3).
- Huron, (1.5) 1.7–2 (2.2).

Av/V:
- Michigan, (1.3) 1.5–1.8 (2).
- Huron, (1.4) 1.5–1.8 (2).

L/D:
- Michigan, (3.3) 3.9–4.3 (4.8).
- Huron, (3.3) 3.7–4.3 (4.9).

The figures show no conspicuous differences between the two forms. The indication of a tendency on the part of Huron specimens to have deeper bodies and shorter snouts may well be due to the preponderance in the Huron collection of local races exhibiting these tendencies.

[69] Figures for Lake Michigan, except those for gill rakers, lateral-line scales, and H/E, are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. The H/E figures are given for 74 specimens 300 millimeters or less in length, those for gill rakers for 151 specimens, and those for scales for 191.

[70] These and succeeding figures for Lake Huron, except those for H/E, are based on an examination of 195 specimens ranging in length from 192 to 512 millimeters. The H/E figures are given for 80 specimens 300 millimeters or less in length.

The color in life and in spirits is not essentially different from that described for the northern Lake Michigan specimens. The intensity of pigment varies with the individual; possibly also with locality. All the specimens collected tend to be darker than those that were obtained in the southern waters of Lake Michigan. Only an occasional individual from Saginaw Bay has been found with the pigment inconspicuous on the abdominal fins, and such pale fish have been among the smallest in the collection.

Pearls are always present during the breeding season on all males and on the majority of females. They occur conspicuously on the body, the head, and faintly on all the fins. On the males they are developed best on the first row of scales above and below the lateral line. They are slightly smaller on the next row dorsad and ventrad and continue to diminish in size to the third or fourth rows above and the fourth or fifth rows below the lateral line. On the surface of the body, dorsad to the third or fourth rows above and ventrad to the fourth or fifth rows below, they are faint and irregularly distributed, often two, three, or more on one scale. On the first four rows above and below the lateral line there is usually only one large pearl on each scale. This is rounded oblong in shape at its base, longer than wide, and is situated in the center, occupying in its extreme development from one-fourth to one-sixth of the exposed scale surface. The pearl is not of uniform thickness. Its two lateral surfaces rise to meet in a line that is distinctly elevated above the remainder of the button and runs lengthwise through its center. Often a much smaller and similarly shaped pearl occurs on one or both sides of the larger one, slightly caudad to its center. Along the cranial half of the lateral line there are often two pearls on each scale, each about one-half the size of those in the first row above and below, or there may be two or three small and unequal pearls. These decrease usually to one small pearl on each scale on the caudal half of the line but remain virtually the same size as on the cranial half. The pearls on the head are well developed and numerous but small and irregularly distributed. They are most numerous on the dorsal surface and on the lateral surface craniad of the operculum. On the suboperculum, interoperculum, and operculum they are fewer, and on the branchiostegal membrane a single row is present on each ray. The premaxillaries and the free edge of the mandible alone are free from pearls. On the pectoral fins they are present in a row running on both sides of the longest ray, being fainter on the inside surface. There are other rows, chiefly on the distal halves of the other pectoral rays. On each side of the longest ventral ray there is a row, and there are often broken rows on the outside of some of the other rays. Besides these, there is a row on the first rays of the dorsal, on the longest rays of the caudal, and on the scales of the adipose fin. The occurrence of pearls in females is approximately the same as in the males, though the maximum development attained is greater in the latter.

VARIATIONS

Racial variations.—There is reason to believe that the whitefish are local in their habits, and therefore races with more or less definite characteristics might be looked for. The existence of no races with distinctive taxonomic characters is disclosed by my analysis of the specimens in my collection, but the material is not sufficiently complete to warrant a positive statement. In certain localities the fish have seemed,

from cursory examination in the field, to have more pointed snouts, but no data on this subject were collected in the field, and in preserved specimens the snout is inclined to be mechanically distorted. However, races may be quite as well marked by physiological differences. Additional discussion on this subject will be found under "Breeding habits."

Size variations.—In Table 85, 10 specimens of various sizes are compared in their chief characters. Separating collected specimens into two size groups, with the dividing line at 300 millimeters, the range of certain proportional characters for the two groups varies more or less. These averages, where they tend to be different, are abstracted below:

L/H:
- Small fish, (4.3) 4.5–4.8 (5).
- Large fish, (4) 4.7–5.

H/E:
- Small fish, (3.8) 4.1–4.5 (4.6).
- Large fish, (4.2) 4.6–5 (5.3).

H/S:
- Small fish, (3.4) 3.6–4 (4.4).
- Large fish, (3.2) 3.4–3.7 (4.2).

L/D:
- Small fish, (3.4) 3.8–4.3 (4.9).
- Large fish, (3.3) 3.7–4.1 (4.7).

The most conspicuous changes involve the head-eye relation, which shows the eye to decrease in relative size with growth. The head and depth appear to be altered but little relative to the body length. From the figures the snout appears to be proportionally shorter in small specimens, but these results are not conclusive, as the snout in large individuals often is deformed in preservation, and slight distortions, even to the extent of a millimeter, would affect the proportions seriously.

METHOD OF CAPTURE

The same methods of capture are employed on Lake Huron as on Lake Michigan and the other lakes. Pound nets in the North Channel and in Georgian Bay yield the greatest production, while on the American shore trap nets figure more extensively as an effective apparatus than on Lake Michigan. Gill nets in the lake are of 4½-inch or larger mesh and depend for profitable use on their catches of whitefish and trout. They may, however, take whitefish on their spawning grounds only, or their catches may be predominantly of whitefish out of a few ports for a short period at other seasons.

GEOGRAPHICAL DISTRIBUTION

We have the assurance of the fishermen that the whitefish formerly occurred all along the shores of Lake Huron, the North Channel, and Georgian Bay. To-day it is virtually unknown from long stretches of the shore line, and in only a few areas does it still remain in numbers. There are two such areas where the fish are fairly abundant on the American shore—in Saginaw Bay and off Alpena—and one of greater extent on the Canadian shore, in the northern and eastern portions of Georgian Bay.

I have collected specimens from most of the ports visited. The data for these are given in Table 84.

SEASONAL MOVEMENTS

The schools of whitefish in Lake Huron, as in the other lakes, engage in migrations toward and away from the shores during the season. From the users of the various types of fishing apparatus I have collected data on these movements.

Data from the pound nets.—In Table 86 are assembled statements on the occurrence of the whitefish in the pound nets set out of various ports on Lake Huron. As might be expected over so wide an area, the movements of the fish vary from port to port. It appears that the fish are often on the grounds in shallow water as soon as the nets are put in in the spring (Point Au Gres, Port Huron, Blind River, Thessalon, Gore Bay, and Cockburn Island). At Killarney the fish are said to be on the shoals when the ice leaves. At a depth of 65 to 75 feet the nets get them only as they move out toward the last of May. The heaviest runs usually are over by the first part of July in the nets set in less than 45 feet (East Tawas, Point Au Gres, Port Huron, Blind River, Thessalon, Gore Bay, Kagawong, and Wiarton). In the nets at 45 to 75 feet off Providence Bay and Killarney and in the 30 to 45 foot nets off Cockburn Island and the Duck Islands the heaviest runs appear from June and July (for Killarney) to August and September (for Providence Bay and Cockburn). The fish are absent entirely in all the nets in 25 to 45 feet of water during August and in some localities earlier (Alpena, East Tawas, Point Au Gres, Port Huron, Blind River, Thessalon, Gore Bay, Kagawong, and Wiarton). At Cockburn Island, the Duck Islands, and Killarney the fish may remain all the summer. The schools return in the fall between the first part of September and the last of October.

Data from gill nets.—The number of whitefish caught in gill nets has decreased to such an extent that few fishermen could operate if they were dependent on their catches of whitefish. Almost every port, however, takes some whitefish in gill nets during the year. The most successful catches, the fishermen say, are those made on mud or gravel bottom. The nets usually are set in the early spring at 10 to 15 fathoms, except off Alpena, where the whitefish are found in April in 30 fathoms, the maximum depth from which the species is known in the lake. The biggest catches are made in 15 to 20 fathoms during July and August. In September the nets are moved into shallower water again, and in October and November the spawning run is taken on the shoals. A few whitefish are taken through the ice in 10 to 20 fathoms off Thessalon and Gore Bay.

The fish caught in the gill nets are smaller, as a rule, than the pound-net fish. Certainly few jumbos (fish over 4 pounds) are caught in the gill nets in summer, while they may be common in the pounds. This fact and the fact that gill nets set in shallow water take few fish have led some fishermen to assert that there are two kinds of whitefish. Neither statement can be disproved. An explanation for absence of fish in gill nets in shallow water has been suggested already. As for the former, it is probable that the 4½-inch mesh is too small for the larger fish.

The data from the gill nets on the movements of the whitefish agree with those from the pound nets. In spring and summer the fish are found by the gill nets in 10 to 15 fathoms when the main schools are in 45 feet (about 8 fathoms) or less. Then when the fish move to deeper water in July and August the pound nets in 45 to 75 feet get them best and the gill nets make their biggest chatches in 15 to 20 fathoms. In the early fall the fish move inshore again and are taken first by the pound nets and later, when they are spawning, by the gill nets. In most localities they probably remain on the shoals under the ice. There are several facts that support this statement: (1) Some fish are caught under the ice in the North Channel; (2) the nets at Point Lookout in Saginaw Bay get the fish as soon as the ice

leaves, while the nets at East Tawas at the entrance of the bay get them as they move out; (3) at Killarney and Port Huron the fish are taken on the shoals when the ice leaves, and at Blind River and Thessalon they are taken in 25 feet of water as soon as the nets are put in in May. Where ice does not form regularly, the heavy winter winds probably drive the fish to deeper water, as off Alpena.

BREEDING HABITS

The size of spawning fish varies with the locality. In general males are smaller than females and mature at less size. One of the largest races in the lake is found off Alpena. Here, on November 16, 1917, males were found on the spawning grounds as small as 2½ pounds in the round, occasionally even 2 pounds, while no females were seen smaller than 3 pounds. Individuals of both sexes occurred as large as 14 pounds, but only females over 5 pounds were relatively common. An examination of the sexual condition of two lifts of whitefish taken in 4½-inch nets, numbering 419 individuals, off Alpena on July 3 and 10, 1923, confirmed these findings, making allowance for increased weight due to growth and to development of the sex glands in the four or five months' period preceding the spawning season. At that season males under 2 pounds in the round usually showed no indication of spawning in the fall, while females usually were not maturing under 2½ pounds. The data for all these specimens of July, 1923, are given below:

Weight in the round	Males		Females		Weight in the round	Males		Females	
	Immature	Maturing	Immature	Maturing		Immature	Maturing	Immature	Maturing
1 pound 8 ounces	2		2		3 pounds 12 ounces		4		6
1 pound 12 ounces	4	3	8		4 pounds		0		5
2 pounds	4	31	24	1	4 pounds 4 ounces		1		1
2 pounds 4 ounces	4	52	40	8	4 pounds 8 ounces		1		5
2 pounds 8 ounces	1	45	32	23	4 pounds 12 ounces				2
2 pounds 12 ounces		37	11	16	5 pounds				1
3 pounds		15	2	16	5 pounds 4 ounces		1		1
3 pounds 4 ounces		10		10	5 pounds 8 ounces				1
3 pounds 8 ounces		7		10					

The fish in Hammond Bay are said to be large also.

The smallest breeding fish were observed in the North Channel. Whitefish taken by J. H. Young off Barrie Island, on September 27, 1919, ranged from 2 to 4 pounds, and virtually all were mature males or females. Mr. Young assured me that this catch was average and that he seldom gets fish larger than 4 pounds. At Kagawong, on November 10, 1917, and in 1919, the fish were no larger than at Gore Bay. Here pearled males less than 1½ pounds in the round were taken occasionally. Alfred Rocque and Charles Lowe, of Killarney, tell me that there is a run of these small fish toward the last of November around the Cloche Islands at the eastern end of the channel. They congregate around these islands to spawn and are so small that many pass through the 4½-inch gill nets that are used to catch them. In Kagawong and Manitou Lakes on Manitoulin Island also the fish are said to run very small.

The time of spawning varies with the locality. In Saginaw Bay, on October 25 1917, I found many of the fish ripe; some of the females were even nearly spent. In the North Channel at Blind River, on November 8, 1917, Mr. Baxter told me, the

94995—29——16

fish were beginning to spawn. Off Barrie Island, Mr. Merrylees, of Gore Bay, told me, they were beginning to spawn on November 10, 1917. Some males of the catches examined here in 1919 as early as September 27 showed pearl organs well developed. At Kagawong, on November 10, 1917, the fish taken were not yet ripe. In Lake Huron, at Alpena, Mich., the spawning season was just beginning on November 16, 1917, according to the spawn takers. The males, they said, had been on the grounds earlier. Furthermore, the time of spawning varies from year to year. What factors influence the ripening of the fish is not known. Some fishermen claim that the moon has something to do with it, but exactly what influence the moon exerts is not clear. It need hardly be said that a closed season for the purpose of protecting the spawning fish, the dates of which are fixed once for all and which holds for every port on the lake, can not accomplish its purpose effectively.

The bottom preferred by the spawning fish is the limestone formation known as honeycomb rock and gravel. Bower (1897) mentions the honeycomb and adds "sometimes on a solidly paved cobblestone bottom, the latter sometimes interspersed with bowlders." Rathbun and Wakeham (1897) say, for Lake Huron, "spawning grounds are found at intervals on rocky or sandy bottom." Milner (1874a) says of the whitefish in the Great Lakes, "the bottoms on the spawning grounds vary in character in different localities, rock, sand, clay, and mud being used indifferently for the spawning beds." Leathers (1911) tells of their spawning on the broad sand flats in Huron County, Mich.

The depth at which the fish spawn varies. Some fishermen say the fish will spawn in as little as 4 feet of water, while others insist that the fish run into this shallow water previous to the spawning season (as do the trout) and that they then repair to 6 to 8 fathoms to spawn. One of the best spawning grounds in the lake lies off Alpena, 6 miles NNE. of Thunder Bay Island, in 8 fathoms of water.

ABUNDANCE

The whitefish in Lake Huron is now much less abundant than formerly. It occurs commonly in relatively few localities. In the vicinity of Alpena and Saginaw Bay on the American side and along certain sections of the North Channel and of the north and east shores of Georgian Bay on the Canadian side it is still the object of special fisheries, but here, as elsewhere, the increased importance of other kinds of fish that are taken incidentally has sustained the fishery in late years.

FOOD

Doctor Hubbs finds, from an examination of the stomach contents of 160 specimens collected off Alpena, Mich., from September 17 to November 2, 1917, and 1919, that Pontoporeia constitued the bulk of the food, supplemented in almost every case by small bivalved and univalved mollusks (Sphærium, Amnicola, etc.). Sand, gravel, cinders, wood fragments, seeds, etc., were present as accidental inclusions in most stomachs, and Chironomidæ larvæ also were of frequent occurrence. Articles occasionally ingested include bryozoan statoblasts, adult land insects, Trichoptera larvæ, Corixidæ, and fish (*Cottus franklinii*). One specimen collected on October 22, 1917, off East Tawas, Mich., had eaten chiefly Sphærium and small gastropods, with some sand and cinders included. Fifteen individuals collected on October

23, 1917, off Bay City in Saginaw Bay were subsisting almost exclusively on the larvæ of the burrowing Mayfly Hexagenia. Sphærium and detritus were present occasionally.

Coregonus clupeaformis of Lake Superior

The whitefish of Lake Superior resembles closely, in body form and other characters, the whitefish of Lake Michigan. The principal systematic characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (24) 26–28 (30).[71]
- Superior, (25) 26–28 (30).[72]

Lateral-line scales:
- Michigan, (74) 81–88 (93).
- Superior, (77) 81–86 (94).

L/H:
- Michigan, (4.2) 4.4–4.8 (5.3).
- Superior, (4.4) 4.6–4.8 (5).

H/E:
- Michigan, (4.4) 4.6–4.9 (5).
- Superior, (4.1) 4.4–4.7 (5).

H/M:
- Michigan, (3) 3.2–3.4 (3.8).
- Superior, (2.9) 3.2–3.4 (3.8).

H/S:
- Michigan, (3.2) 3.4–3.7 (4.1).
- Superior, (3.2) 3.4–3.8 (4.2).

Pv/P:
- Michigan, (1.5) 1.7–2 (2.3).
- Superior, (1.4) 1.6–1.9 (2.3).

Av/V:
- Michigan, (1.3) 1.5–1.8 (2).
- Superior, (1.3) 1.5–1.8 (1.9).

L/D:
- Michigan, (3.3) 3.9–4.3 (4.8).
- Superior, (3) 3.7–4.3 (4.7).

The most important differences that the figures show are a proportionally larger eye for Superior fish, but this character is known to decrease in proportion with growth, and as the Superior specimens average smaller and therefore might be expected to differ in this way from the Michigan fish, the data can not be regarded as establishing differences between the two forms.

The general appearance in life is essentially silvery, though less so, perhaps, than in most Leucichthys. The back, as a rule, is pale pea green, palest behind the dorsal, fading toward the tail, and obscured by wide bands of pigment around the free edges of the scales and fins and fine scattered pigment over the entire surface. The color extends on the sides to about the fourth or fifth row of scales above the lateral line and begins then to change to a blue, which is strongest below the line and fades toward the colorless belly. The silvery layer begins to become conspicuous on the ninth row above and reflects on the sides a superficial brassy to purplish iridescence, which is most conspicuous above the lateral line. The top of the head is cartilaginous white, frequently with a flesh tone, but it is often so heavily dotted with pigment as to have an almost black cast and to conceal the green patches lying in the cranial cartilages. There is a more or less evident trace of green in the preorbital area. The premaxillaries, maxillary, and mandible also show flesh tones. Otherwise the head is silvery with the reflections of the sides. The fins are whitish, more or less pigmented, sometimes tinted a flesh color at the base, especially the pectorals.

The color in alcohol is dark, like that recorded for Michigan specimens, except that the specimens from Ontonagon, Mich., the smallest ones in the collection, show

[71] Figures for Lake Michigan, except those for gill rakers, lateral-line scales, and H/E are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. The H/E figures are given for 52 specimens between the lengths of 300 and 483 millimeters; those for gill rakers for 151 specimens, and those for scales for 191.

[72] These and other figures for Lake Superior, except those for H/E are given for 109 specimens ranging in length from 180 to 382 millimeters. The H/E figures are given for 55 specimens from 300 to 382 millimeters long.

little or no pigment on the abdominal fins and reduced pigmentation elsewhere, as in the case of the small fish of southern Lake Michigan. The only other small fish (two taken off Marquette, Mich.) are as heavily pigmented as the largest specimens taken from the same locality, so that it is not certain that these small fish from Ontonagon would become darker with age, nor is it certain that all small fish from Marquette would also be dark.

Pearl organs no doubt are developed by both sexes when spawning, but no spawning fish were collected. It is probable that the descriptions of these excrescences given for Lake Huron specimens will fit those from Superior.

VARIATIONS

Racial variations.—Relatively few specimens have been obtained from any locality, as may be seen from Table 87, and the collected specimens indicate that in only one area (Black Bay, a long, rather inclosed bay on the north shore) do the fish seem to have developed any peculiarity of structure that distinguishes them from their relatives in other parts of the lake. The pale fish from Ontonagon are not considered further, as it is not known definitely that pigmentation may not increase with age. The Black Bay whitefish appear to be notably deeper bodied, on the whole, than those from the open lake. The meager data on hand also indicate that the bay fish tend to have fewer lateral-line scales, as in the case of the Lake Erie race, which is also deeper bodied. L/D values for Black Bay specimens and for those from other parts of the lake are compared below:

	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7
Black Bay	1	0	2	3	3	6	3	5	4	0	2	1	1	1	1	-----	-----	-----
Lake Superior	-----	-----	-----	-----	-----	1	1	4	2	6	13	8	7	5	7	5	2	1

The *artedi* in Black Bay are known also to be deeper bodied (see p. 500), and both the whitefish and the herring show the same general characters that these species exhibit in Lake Erie. It is probable that in each case the peculiar characteristics are a response to the environment. While there are no data to indicate exactly what the environmental conditions are, it is known that Black Bay is conspicuously shallower and warmer than Lake Superior and even than other much smaller but more open bays near it; and it is assumed that Lake Erie, on account of its shallowness and southerly location is the warmest of the Great Lakes. I have no temperature readings for Lake Erie, but records 9 to 25 in Table 13 show the greater warmth of Black Bay as compared with Lake Superior a few miles outside of the bay and with the more open channels and bays of the north shore. Temperature readings for other parts of Lake Superior, given in the same table, all indicate that the main lake is warmed but slowly and that even at the end of the summer its heat budget is not large. In the figures above it is of particular interest to observe that while the surface temperature in Black Bay was not as high on July 20, 1922, as in Simpson Channel, Moffat Strait, or Armour Harbor on August 5 and 10, 1922, yet the temperature at 8 fathoms was from 3.1° to 6.3° warmer than that recorded at only 4 to 5 fathoms below the surface at these points, and at 8 fathoms was 4.4° warmer than the surface water a few miles outside the bay off Thunder Cape Light on the same day. It is noteworthy also in this connection that the whitefish and herring of Lake Winnipeg and certain other

shallow lakes, which must become fairly warm in summer, show the same peculiar features.

Size variations.—The same kind of variation of proportions with size is exhibited by Superior specimens as has been recorded for those of Michigan. In Table 88 are compared in detail 10 individuals of varied sizes. Separating the specimens of the collection into two groups, according as they are more or less than 300 millimeters in length, the only character that appears to be different in the two groups is the H/E ratio. The figures for the smaller fish are (3.8) 4.2–4.4 (4.7); for the larger ones (4.1) 4.4–4.6 (5), indicating that the eye becomes smaller with growth, relative to the head. Of course, all the fish in the collection are fairly uniform as to size, the length of most of them falling within 50 millimeters of the dividing point of the two groups; and if there were greater disparity in size between the groups compared, the differences in this ratio would become much more conspicuous and other ratios also might be found to differ.

METHOD OF CAPTURE

Whitefish are taken chiefly by means of pounds and gill nets, as in Lake Michigan, but a few are taken by other apparatus. The pound nets are located chiefly on the north shore, but there are a few on the southern and eastern shores, most of which yield whitefish. Gill nets, too, are used for whitefish in these areas, but the catches are mixed with trout, for the most part, and here, as in the other lakes, the gill-net industry would long since have perished if it had been dependent on the whitefish alone.

GEOGRAPHICAL DISTRIBUTION

Table 87 shows data for specimens collected from various points along the north, east, and south shores. The records are shown platted on the lake chart in Figure 3. Whitefish are known to exist at all ports on the lake, but they are rare in many sections, particularly on the west shore, where only occasional specimens are taken. They occur around Isle Royale and Michipicoten Island, also, and Will Parker says he has taken stray specimens on Stannard Rock Reef (separated from the mainland by a 30-mile stretch of water, which in most places is from 50 to 100 fathoms in depth).

Lake Superior does not offer particularly favorable conditions for littoral fishes, and the whitefish, therefore, has never been more than locally common. Excepting the bays and the south shore, there is elsewhere only a narrow zone along shore, in many sectors barely a mile wide, in which bathymetric conditions are favorable, to say nothing of bottom conditions. Many of the bays even are too deep over most of their extent, and along the south shore there is only a strip not more than 5 miles wide over which there is water of suitable depth. The bottom, except on the south shore and in the bays, is largely rocky, where the whitefish probably find little food; and the low temperature of the lake's waters also probably retards the development of food organisms, even where conditions are otherwise favorable.

SEASONAL MOVEMENTS

The whitefish behave in Lake Superior as in the other lakes, moving to and away from the shoals during the season.

Data from the pound nets.—Lake Superior often is still covered with ice by May 1, so that the driving of the pound nets may not be completed before the 1st of June.

(See Table 89.) The whitefish are found inshore as soon as or shortly after the nets are set and are at their best in June and July—earlier in those nets to the south or in shallow bays (Whitefish Point, Marquette, Black Bay and Nipigon Bay), and later in other places (Gargantua and Batchawanna). In the shallowest nets the fish are practically absent after the middle of July, and after early August they are taken only in the deepest nets. At Whitefish Point some are said to have been caught in the 90-foot nets throughout the summer. The runs return in the fall (if the nets are not blown out before), from mid-September to late October, depending on the locality.

Data from the gill nets.—Gill nets are set for whitefish in most of the areas where they are caught in pounds. As soon as the ice breaks the whitefish are found along the banks in from 20 to 35 fathoms. When the water temperature rises in June and July the nets are moved shallower. When the water is warmest (in August) the fish leave the shoals, and then the catches, as a rule, decrease. The inshore run in the fall is again a favorable time for the gill netters, though often the weather is too inclement to risk the netting in the shallow water.

John MacMillan, of Sault Ste. Marie, Ontario, informs me that in the summer whitefish can be taken in commercial quantities in the 60 to 70 fathom holes off the Lizard Islands. Other fishermen have found stray individuals in water as deep outside the main banks, and originally when the species was more abundant captures at that depth along the shores were still more common, probably due to the overcrowding of the more favorable shoal areas.

Thus, all the data we possess on the movements of the whitefish indicate that for the most part they are to be found in early spring at depths of 20 to 35 fathoms, probably in those localities where shallower water is too disturbed by currents to offer suitable conditions. As the season advances they move onto the shoals, leaving these again when the waters become warmest, and then occurring rather sparingly anywhere until the schools come ashore again in the fall to spawn. While they prefer relatively shallow water at all times, as in other lakes, there is evidence that at times they occur at 60 or 70 fathoms, where such depths are near shallow areas.

The fingerlings probably live along the beaches during most of the year (Hankinson, 1914).

BREEDING HABITS

The average time of spawning for the species is during the month of November, though here, as elsewhere, the spawning season is not uniform for every locality on the lake. It appears that, as a rule, the northshore whitefish spawn earlier than those in other sectors. If it is a question of lowered temperature that induces spawning, the phenomenon probably can be explained, inasmuch as the bays, which are shallower and more northerly, probably cool more rapidly than the main lake.

No extensive spawning grounds are known, but areas suitable for spawning are scattered along most of the shore stretch where whitefish are found in the summer. The bottom selected is sand, gravel, or small stones at depths from 1 to 12 fathoms.

Nothing is known of the breeding behavior of the species in Lake Superior.

The size of the whitefish at maturity varies with the locality, as in the other lakes. The whitefish from Rossport and in Black Bay are notably small, according to the fishermen, not often exceeding 4 pounds in weight. I have collected specimens with maturing gonads less than 300 millimeters in length from these localities, though

individuals of either sex were not often seen maturing under 320 millimeters in length. These fish weigh about 1 pound in the round. Maturing of the sex organs in small fish was observed in Batchawanna specimens, though Frank La Pointe, who fishes there, says the fish run large and seldom spawn under 3 pounds. Specimens from Marquette, Mich., between the lengths of 300 and 348 millimeters, were not approaching maturity. Nothing is known of the size at maturity at other places.

ABUNDANCE

What has been said about the abundance of the whitefish in Lake Michigan applies with equal force to Lake Superior and the other Great Lakes. Whitefish are now common nowhere, and the lake's entire production for 1922, the last year for which complete census figures are available, amounted to about 680,000 pounds, as compared with 4,191,000 pounds reported in 1890. The bays and shoals around the various islands are the last strongholds of the species, and the quantity of the production in these areas fluctuates from year to year. In some such areas, when the species has been so reduced that commercial operations are no longer profitable, the economically enforced respite from persecution probably enables the species to increase in numbers again. The Whitefish Point grounds, the most famous on the lake, now, however, are believed to have been entirely depleted for many years.

Coregonus clupeaformis of Lake Nipigon

The whitefish of Lake Nipigon closely resembles that of Lake Michigan. There are a few differences, which are apparent from a comparison of the main systematic characters capable of numerical expression listed below:

Gill rakers on the first branchial arch:
- Michigan, (24) 26–28 (30).[73]
- Nipigon, (26) 27–29 (30).[74]

Lateral-line scales:
- Michigan, (74) 81–88 (93).[75]
- Nipigon (76) 78–85 (89).

L/H:
- Michigan, (4.2) 4.4–4.8 (5.3).[76]
- Nipigon, (4.1) 4.3–4.5 (4.8).

H/E:
- Michigan, (3.8) 4–4.4 (4.8).
- Nipigon, 3.9–4.3 (4.7).

H/S:
- Michigan, (3.2) 3.4–3.7 (4.1).
- Nipigon, (3.2) 3.4–3.7 (4.1).

H/M:
- Michigan, (3) 3.2–3.4 (3.8).
- Nipigon, (2.8) 3–3.3 (3.6).

Pv/P:
- Michigan, (1.5) 1.7–2 (2.3).
- Nipigon, (1.5) 1.6–1.8 (2).

Av/V:
- Michigan, (1.3) 1.5–1.8 (2).
- Nipigon, (1.2) 1.5–1.6 (1.7).

L/D:
- Michigan, (3.3) 3.9–4.3 (4.8).
- Nipigon, (3.1) 3.5–4 (4.2).

The figures show no conspicuous differences between the two forms, and it is likely that, if more specimens of comparable size were studied, the apparent ones might disappear. There is a possibility that the maxillary may be found to be proportionally longer in the Nipigon form.

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[73] One hundred and fifty-one specimens.

[74] These and succeeding figures for Lake Nipigon, except those for H/E, are based on an examination of 34 specimens ranging in length from 203 to 409 millimeters. The H/E figures are given for 25 specimens 300 millimeters or less in length.

[75] One hundred and ninety-one specimens.

[76] These and succeeding figures for Lake Michigan, except those for H/E, are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. The H/E figures are given for 74 specimens 300 millimeters or less in length.

The color in life has not been recorded carefully, but it is paler than that of the Michigan form. Most of the preserved specimens have notably less pigment than those from the northern waters of Lake Michigan, though it is distributed over the same areas. They lack the dusky hue of the back, for the most part. One specimen, however, taken off the Blackwater River (a muskeg stream), is as dark colored as any specimen collected anywhere in the Great Lakes.

PEARL ORGANS

No fish were collected by me during the spawning season, but the fishermen all agree that the spawning fish develop pearls. These probably are more or less similar to those exhibited by breeding fish in the other lakes.

VARIATIONS

Racial variations.—Specimens have not been obtained in sufficient numbers to study local variation, and from the material at hand, which originated from various sectors of the lake (see fig. 2), there are no indications (except for the muskeg color of the specimen referred to in a previous paragraph) that local races, if they do exist, are characterized by conspicuous external features.

Size variations.—In Table 91 the five largest and the five smallest fish of my collection are compared extensively in certain systematic characters. The chief differences between the two size groups appear to be the usual ones, namely, a relatively larger head and eye in the smaller fish. Possibly a study of more specimens would reveal other changes with growth.

METHODS OF CAPTURE

Gill nets of 4½-inch mesh and pound nets are the only apparatus employed in the whitefish fisheries on Lake Nipigon. The gill netting is usually spun of sea-island cotton on account of the large quantities of suckers and other rough fish that are taken. The latter are very destructive to the more expensive linen netting generally used in the Great Lakes.

GEOGRAPHICAL DISTRIBUTION

While the data given in Table 90 and platted on the lake chart in Figure 2 for the specimens I have collected do not show a wide distribution of the whitefish in the lake, the species actually may be found (according to the fishermen) in commercial quantities almost everywhere in depths of less than about 35 fathoms. Dymond (1926) records having taken specimens as deep as 50 fathoms.

SEASONAL MOVEMENTS

The fishing season begins when the ice leaves (usually in early May) and continues until the lake freezes in late November. According to the fishermen, most of the lake is relatively shallow, with holes of 25 to 35 fathoms scattered here and there. There is water as deep, at least, as 67 fathoms off Livingston Point, but areas covered by such depths are relatively limited. In spring the fishermen set their nets on the banks of these "bowls" in 17 to 35 fathoms and through the season

move them up and down the banks. In spring and fall the fish are likely to be shallowest and in midsummer deepest, though the fishermen say they are not able, usually, to go shallower than 15 fathoms or they will load their nets with suckers, and deeper than 35 fathoms they seldom find whitefish in commercial quantities. However, several fishermen claim to have made profitable lifts from depths of 40 and even 45 fathoms.

BREEDING HABITS

According to John McIver and Andrew Sutherland, the whitefish spawn from the middle to the end of November. They select hard bottom and come into the shallowest water at that time. Nothing is known of their spawning behavior.

The Nipigon fish do not grow large. One of the largest specimens ever collected measured only 615 millimeters and weighed probably about 10 pounds, while specimens over 4 pounds are relatively uncommon. It is not known definitely at what size the fish mature sexually, but Mr. McIver says they may be sexually mature at less than 2 pounds in the round. I have only nine fish over 300 millimeters long, three of which have been eviscerated; and of the six fish in the round two males and a female of each group are immature at a length of 317, 325, and 321 millimeters, respectively (weight about 1 to 1¼ pounds), while the mature fish measure 331, 409, and 373 millimeters, respectively. All fish smaller than 300 millimeters uniformly show no maturity of the gonads. Superficial examination indicates, also, that the fish grow slowly. A slow rate of growth might be expected for fish from waters that are covered with ice for so long a period each year.

ABUNDANCE

The whitefish is the most important and most abundant commercial fish in Lake Nipigon. No other fish are marketable, except the lake trout and wall-eyed pike. Leucichthys of several species and suckers are very abundant but are not yet commercially valuable at points so far removed from the markets.

The lake was opened to commercial fishing in 1916. Production was insignificant that year, but for most of the time since the fisheries have been prosecuted by some dozen steam and gasoline boats operating gill nets. The number of fishing licenses has been limited more or less, and the production of the boats has been restricted to 80 tons a year per steam tug and 40 tons per gasoline vessel. The peak of production was reached in 1919, according to the Ontario report upon game and fisheries, when 1,620,970 pounds of whitefish, 617,900 pounds of trout, and 30,035 pounds of wall-eyes were taken. Figures for 1920 and 1921 show a continued decrease.

If all the whitefish grow as slowly as my specimens indicate, the reason for the decline in production is obviously due to the fact that the fish have been caught more rapidly than they were being produced, and in that case a serious depletion may be expected soon.

Coregonus clupeaformis of Lake Erie

The whitefish of Lake Erie is very similar to the Michigan form except that it is deeper bodied, as a rule, and the predorsal contour, therefore, is often strongly arched in smaller fish. Fish may be "bowbacked" as small as 2½ pounds round. All the whitefish are by no means thus humped at the nape, and often specimens weighing

3 or 4 pounds are found in which the predorsal contour line is as smooth as in the fish of the upper lakes. Such fish were particularly common off Merlin, Ontario, in November, 1924. The principal systematic characters of the two forms that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (24) 26–28 (30).[77]
- Erie, (25) 26–29 (30).[78]

Lateral-line scales:
- Michigan, (74) 81–88 (93).
- Erie, (73) 77–86 (93).

L/H:
- Michigan, (4.4) 4.5–4.8 (5.3).
- Erie, 4.7–5 (5.3).

H/E:
- Michigan, (4.4) 4.6–5.
- Erie, (4.3) 4.8–5 (5.2).

H/S:
- Michigan, (3.2) 3.4–3.8 (4.1).
- Erie, (3.3) 3.4–3.8 (4).

H/M:
- Michigan, (3) 3.2–3.3 (3.7).
- Erie, (3) 3.1–3.3 (3.7).

Pv/P:
- Michigan, (1.5) 1.7–1.9 (2.3).
- Erie, (1.6) 1.7–1.9 (2).

Av/V:
- Michigan, (1.4) 1.6–8 (1.2).
- Erie, (1.4) 1.6–1.7 (1.8).

L/D:
- Michigan, (3.3) 3.9–4.2 (4.8).
- Erie, (3.1) 3.3–3.6 (3.8).

Pectoral rays:
- Michigan, (14) 15–17.
- Erie, 13–15

Scale rows:
- Michigan, (46) 48–50 (52)–(36) 37–39 (40)–25–27 (28).
- Erie, (45) 46–48 (50)–(34) 35–37 (39)–(24) 25–27.

The two forms are in close agreement in respect to all proportions except those involving body depth, head in relation to total length and the eye, and it is probable that this disparity would be reduced in the former and eliminated in the last two if the specimens in the two groups were strictly comparable. In the matter of counts there appear to be differences. The Erie form tends apparently to have fewer pectoral rays, fewer scale rows, and possibly fewer lateral-line scales; but except for the latter character too few specimens have been examined to permit any conclusions.

The color in life is slightly paler than that described for Superior specimens. The iridescence of the sides also is fainter and more often pinkish. Alcoholic specimens show pigment distributed in the same manner as has been described for the form from northern Lake Michigan, except that pigmentation is much less intense. The smoky hue of the back and fins is much reduced. The pectorals are often nearly immaculate.

Pearl organs are developed in the breeding season by both males and females, and their development is like that described for Huron specimens.

VARIATIONS

Racial variations.—No studies have been made to determine the occurrence of local races.

Size variations.—The only whitefish seen have been those that were marketable, and there is not sufficient inequality in size to ascertain how the body changes with growth. It is probable that such changes are like those outlined for the species in other waters.

[77] Figures for Lake Michigan are given for 52 specimens ranging in length from 300 to 483 millimeters, except that those for gill rakers are given for 151 specimens, for lateral-line scales for 191, for pectoral rays and scale rows for 20.

[78] Figures for Lake Erie are given for 18 specimens ranging in length from 291 to 402 millimeters, except that those for gill rakers are given for 100 specimens and those for lateral-line scales for 324.

METHODS OF CAPTURE

The whitefish is caught in Lake Erie by means of gill nets, trap nets, and pound nets. In the eastern half of the lake gill nets are employed most commonly, while trap nets are most abundant on the south shore, chiefly over the western half, and pounds are used most at points along the north shore. The whitefish is now so reduced in numbers that gill-net fishing for whitefish is being discontinued gradually everywhere on the lake; but the use of the other nets is not affected so heavily, as this apparatus takes all kinds of fish and is not dependent on the whitefish for profit.

GEOGRAPHICAL DISTRIBUTION

Relatively few specimens have been collected, though many hundreds have been seen. The data for collected specimens are given in Table 92 and show records from four ports of the south shore. At least a few whitefish are to be had at some season out of any port on the lake, and formerly they were more or less abundant all along the shores and throughout the lake's extent, except possibly in the deepest part of the eastern depression.

SEASONAL MOVEMENTS

As in the other lakes, the whitefish approach and retreat from the shores during the season.

Data from the pound nets.—Pound nets are used most widely in the Canadian waters on the north shore of the lake. Data collected from the fishermen who operate such gear out of the ports of Pelee Island (John McCormick), Merlin (A. Crewe), Ridgetown (W. D. Bates), Port Bruce (W. McGuire), and Port Dover (A. B. Hoover and W. F. Kolbe) show that the whitefish run best in the pounds during the month of May. After June 1 to 15 the run is over entirely. In the fall the fish reappear toward the last of October and run through the month of November. In most ports the fall run exceeds that of the spring.

On the south shore few pound nets are employed, such apparatus being replaced by trap nets. At the west end of the lake whitefish are taken no longer except in the fall, when they appear on the shoals on the western flat in late October and during November.

Data from the gill nets.—In years past when whitefish were common throughout the lake they were taken in suitable gear during any part of the season. Now the employment of gill nets, which depend on whitefish alone for their profitable use, is restricted to certain weeks of the fishing season. At the eastern end of the lake the period of profitable netting for whitefish is longest. Out of Erieau, Ontario (Norman Macaulay), Port Stanley, Ontario (C. Finlay and Arthur Glover), Dunkirk, N. Y. (Walter Murray, George O'Brien, and Thomas Desmond), Barcelona, N. Y. (H. Monroe), Erie, Pa. (Joseph Ferguson), and Ashtabula, Ohio (C. Owen), nets are set in the spring around March 15 in Canadian waters outside of the 10-mile zone reserved for pound-net fisheries, and in American waters at depths of 10 to 25 fathoms. In late years the season lasted for four to six weeks, or until May 1 or 15. In July the nets again were put in the deep waters of the eastern end of the lake, and the season continued to August 1 to 15. In the fall whitefish have been available out

of most ports on the lake except off the Canadian shore, and gill nets have been employed frequently to take them. The season ranges usually from October 1 into December, depending on the locality and the weather. Out of Dunkirk and Barcelona nets were set for whitefish into the month of January.

The data collected from the fishermen on the lake indicate that the whitefish are found by gill nets in early spring in the deeper waters, especially in the eastern half of the lake. In May the schools move onto the shoals but retreat again into deeper water in early June. In the deep water at the eastern end of the lake they have been found in commercial quantities during July. Thereafter, until the water cools in the fall, usually none are taken by any apparatus; but in October the gill nets get them again in the deeper waters, and later they move shallower and are caught in the pounds and traps. Later still they repair again to deeper water.

There is a widespread belief among American fishermen that there are only a few schools (or perhaps one) of whitefish in the lake and that these fish summer in the deep water of the east and migrate in the fall to spawn on the reefs to the west. Such a view places too much emphasis on the observation by the fish of the international boundary line and does not take into consideration at all what happens on the Canadian shore, where there have also been extensive whitefish fisheries. It is rather likely that there are several localized schools, none of which undertake extensive coastwise migrations. An intensive study of the fish of the various localities should throw light on this subject; or, better, if marking were feasible, actual migrations could be traced.

BREEDING HABITS

The whitefish spawn generally from about November 20 into December. The season, of course, varies from year to year. On November 30, 1920, at Sandusky and Toledo, Ohio, many of the fish had not yet begun to spawn, and at Merlin and Ridgetown, Ontario, spawning had not begun on November 24, 1924.

The largest spawning grounds of the lake are located around the Bass Islands and Pelee Island, on the limestone reefs in their vicinity, and off Port Maitland. Small reefs, some of which are known to be frequented by whitefish, are scattered along the shores of the lake. The bottom is largely honeycomb limestone rock or gravel, and the water is usually less than 30 feet deep. The western spawning grounds have been virtually deserted since 1920, which was the last good year, on account of the pollution by the Detroit River water, the fishermen believe.

The minimum size of spawning fish is not known exactly, but at Merlin, on November 24, 1924, spawning males were seen as small as 1¼ and 1½ pounds in the round. Many of the fishermen on the north shore inform me that males of this size commonly spawn, but that they do not recall seeing mature females so small.

Little is known of the spawning behavior of the species except that Charles Dircks, of Put in Bay, Ohio, says the males clean portions on the rocks 2 to 10 feet square and that he has seen the male accompanying the female while spawning on these cleaned areas.

ABUNDANCE

Early records show more whitefish taken on the western flats (where there are now no whitefish at all) than are taken in all Lake Erie. In the last five years

the species has been of irregular occurrence everywhere and the average annual yield has been low. Around the beginning of the century there was also a period of low production, after which the species increased again. At that time the large-meshed nets went out of use because no other species could be caught with them and the quantity of trap nets and pound nets (which depended largely on the whitefish for profitable employment) decreased in numbers, and with the abatement of the persecution it had sustained, the stock had an opportunity to recover. At that time, too, the Canadian fisheries were being exploited but little, so that there was a kind of natural preserve across the border, besides which large quantities of fry were planted annually.

The present depletion is much more serious than any recorded before, and there is less reason to hope that time will repair it. The use of large-meshed nets is being discontinued again, but the other apparatus is not at all affected, because other species, which were not marketable 20 years ago, are being taken in profitable quantities; and even where whitefish are the mainstay of the fisheries the increased price paid per pound, which in 1922 was over two and one-half times the average price in 1903, permits the continuation of the fisheries even though the supply is less. Canadian fisheries also have expanded enormously in the last 15 years, and the waters across the boundary probably are as exhausted now as our own, so that there is much less of a reserve stock than formerly. The recuperation of the whitefish is impeded further by the excessive pollution of the Detroit and other rivers, also, which, the fishermen say, has driven them off the best spawning grounds in the lake.

ABNORMAL FORMS

The "mule whitefish."—Specimens of what are usually considered hybrids between *Coregonus clupeaformis* and *Leucichthys artedi* are taken occasionally out of many of the lake ports. Their occurrence has been known long, and specimens have been described. These so-called hybrids are frequently of greater average size than even the whitefish. I have a photograph of a male taken by W. D. Bates at Ridgetown on the north shore that weighed 11 pounds, 15 ounces.

A specimen 282 millimeters long was taken by me at Toledo, Ohio, on November 27, 1920. This fish was a male and showed pearl organs. A numerical expression of many of its systematic characters is given in Table 93, and a drawing of the head is shown in Figure 31, *A*.

The body outline is elliptical in side view, like that of a deep-bodied herring. The caudal peduncle also is short and thick, as in the herring *albus*. The premaxillaries are inclined backward, as in the whitefish, but in this specimen the angle is bent little more than 90°. The long adipose and maxillary are other characteristics of the whitefish. The number of gill rakers is clearly intermediate between that of the two forms. The other characters exhibited by this fish are such as are common to both of the supposed parents.

Artificially reared whitefish.—The New York aquarium reared whitefish from eggs of Lake Erie parents hatched in January, 1913. An account of their treatment is given by Mellen (1923). Thirty-two of these fish, which died during the years 1921 and 1922, were received from the aquarium authorities and are now preserved

in the University of Michigan collection. These fish ranged in length from 203 to 328 millimeters, and many of them were sexually mature.

The body parts show great modification in all the specimens, and no e of them closely resemble any whitefish taken in the Great Lakes. The most striking differences are changes in the shape of head parts. The head throughout is much deeper than in normal whitefish, and its dorsal contour usually is decurved conspicuously

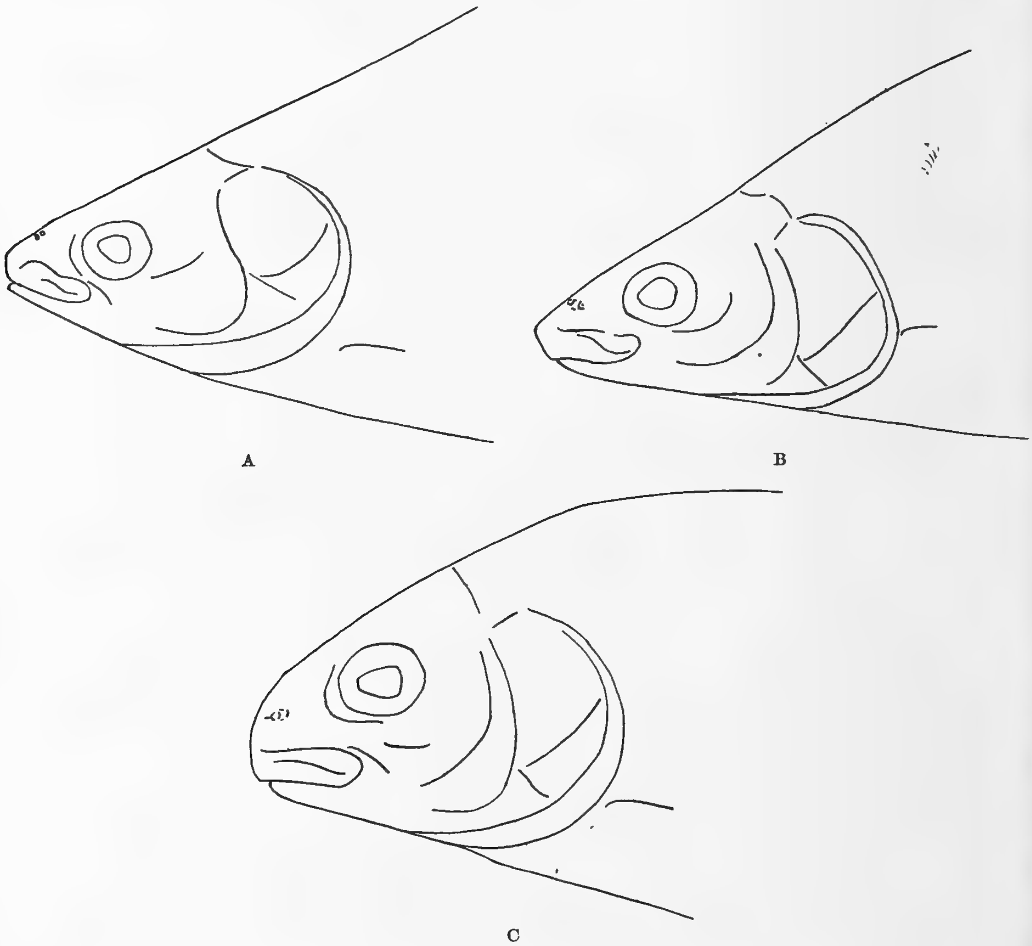

FIG. 31.—Comparison of the heads of the "mule whitefish" (A), a normal whitefish (B), and a New York aquarium specimen (C). The fish were about equal in size—A, 282 millimeters; B, 305 millimeters; and C, 315 millimeters

anterior to the orbit. (See fig. 31, *C*.) The premaxillaries are often vertical in position, which is not known to be the case in normally reared individuals. The head is broader, especially across the snout, and the adipose is much larger usually.

The characters that can be expressed numerically also are interestingly different. All the specimens from the Great Lakes less than 300 millimeters long (many of them less than 200 millimeters long), are combined for comparison in certain characters with those of the New York aquarium. The complete figures are given below:

L/H:	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5	5.1
All lakes	--	--	--	--	--	2	6	16	31	41	48	44	17	8	1
Aquarium	2	1	1	--	1	3	3	4	7	7	1	2	--	--	--

H/E:	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9
All lakes	--	--	--	--	4	5	23	25	31	42	45	30	5	2	1	1
Aquarium	2	1	3	5	3	6	4	3	--	3	--	1	--	--	--	--

H/M:	2.8	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8
All lakes	--	1	2	22	48	40	45	30	13	5	5
Aquarium	2	5	7	9	4	3	--	--	--	--	--

H/S:	2.9	3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4
All lakes	--	--	--	--	6	17	17	32	36	28	31	23	8	5	--	1
Aquarium	1	--	2	5	4	9	8	1	--	2	--	--	--	--	--	--

Pv/P:	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3
All lakes	--	--	2	8	19	33	44	36	45	18	4	2
Aquarium	3	3	11	8	4	2	--	1	--	--	--	--

Av/V:	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9
All lakes	--	--	--	2	8	58	71	46	24	7
Aquarium	1	1	1	2	5	9	11	1	--	--

Gill rakers:	23	24	25	26	27	28	29	30	31	34
All lakes	--	2	35	136	172	180	79	15	3	--
Aquarium	5	7	8	5	3	2	--	--	--	1

It is clear that the artificially reared specimens have a proportionally longer head, eye, maxillary, snout, and paired fins, and fewer gill rakers than naturally reared fishes. (The one fish with 34 rakers (223 millimeters long) is probably a "mule whitefish.")

Aquarium conditions thus have produced or permitted the development of individuals that are strikingly different from those that are found in nature. Even characters that are considered generic, such as the position of the premaxillaries, have been altered. These observations are of especial interest in view of the striking differences that have been found to obtain in certain species of Leucichthys between forms of a species group.

Coregonus clupeaformis of Lake Ontario

The whitefish of Lake Ontario resembles that of Lake Michigan. The principal characters of the two forms are compared below:

Gill rakers on the first branchial arch:
- Michigan, (24) 26–28 (30).[79]
- Ontario, (25) 27–28 (31).[80]

Lateral-line scales:
- Michigan, (74) 81–88 (93).
- Ontario, (75) 80–88 (92).

L/H:
- Michigan, (4.2) 4.4–4.8 (5.3).
- Ontario, (4.4) 4.6–4.9 (5.2).

H/E:
- Michigan, (4.4) 4.6–4.9 (5).
- Ontario, (4.2) 4.7–5 (5.3).

H/M:
- Michigan, (3) 3.2–3.4 (3.8).
- Ontario, (3) 3.2–3.4 (3.7).

H/S:
- Michigan, (3.2) 3.4–3.7 (4.1).
- Ontario, (3.3) 3.6–3.8 (4.2).

Pv/P:
- Michigan, (1.5) 1.7–2 (2.3).
- Ontario, (1.4) 1.7–2 (2.2).

Av/V:
- Michigan, (1.3) 1.5–1.8 (2).
- Ontario, (1.3) 1.6–1.8 (1.9).

L/D:
- Michigan, (3.3) 3.9–4.3 (4.8).
- Ontario, (3.4) 3.7–4 (4.3).

[79] Figures for Lake Michigan, except those for gill rakers, lateral-line scales, and H/E, are based on an examination of 126 specimens ranging in length from 179 to 483 millimeters. The H/E figures are given for 52 specimens between the lengths of 300 and 483 millimeters, those for gill rakers for 151 specimens, and those for scales for 191.

[80] These and other figures for Lake Ontario, except those for lateral-line scales and H/E, are based on an examination of 39 specimens ranging in length from 253 to 444 millimeters. The H/E figures are given for 27 specimens over 300 millimeters long, and the scale figures have been supplemented by counts of 160 specimens, not preserved, from Brighton, Ontario.

The figures indicate no significant differences between the two forms, and such inequalities as are apparent probably would be reduced by a study of more specimens.

The color in life is not different, so far as has been observed, from that described for Superior specimens, and alcoholics do not differ materially in color from the preserved Superior specimens, except possibly pigment is less abundant, on the average, though it is distributed in the same areas.

Pearl organs are developed in the breeding season by the adults of both sexes. Only a few specimens ready to spawn were seen, and in these the development of the pearls was like that described for the Huron form.

VARIATIONS

Racial variations.—There are not enough collected specimens to analyze for the purpose of ascertaining the existence of local races. What specimens have been assembled do not indicate that these races, if they do exist, are marked by external features.

Size variations.—Most of the collected fish are approximately of the same size, but in Table 95, 10 fish are compared extensively, among which are the largest and the smallest specimens in the collection. The number of specimens is insufficient, of course, but it is apparent from these figures that the usual changes with growth, affecting at least the relative size of the head and the eye, are manifested by the Ontario whitefish also.

METHODS OF CAPTURE

The commercial use of pound nets is prohibited on the shores of Lake Ontario, and the trap and fyke nets are not particularly successful in taking whitefish, so that virtually all the whitefish marketed are produced by gill nets, which are usually of 4½ or 4¾ inch mesh.

GEOGRAPHICAL DISTRIBUTION

In Table 94 are given the data for the specimens I have collected. These are platted on the chart of the lake in Figure 7. In addition to actual specimens, records of the occurrence of the species are included in the account of the habits of the species. From both sources it is apparent that the species is distributed along the lake's shores, though it is by no means abundant enough everywhere to be of commercial significance.

SEASONAL MOVEMENTS

Along the Canadian shore, where the whitefish is most abundant, the fishermen say the fish are to be found on the shoals when the ice leaves in April (Brighton, Port Hope, Bronte). In June they move into deeper water and are then fished for at about 8 to 12 fathoms. As the water becomes warmer they retreat still deeper and in August may be caught down to depths of 25 fathoms. The best lifts are made when the fish are in this deep water. A lift witnessed by me on August 27, 1923, off Sandy Pond, N. Y., from 24 fathoms had from 35 to 62 fish per 20 rods of net of 4¾-inch mesh. The nets had been set three nights. In September the weather usually is unsettled and the fish probably rise from the bottom; at least, not many are caught. In October they move inshore again, and in November the schools are back on the

shoals to spawn. There are no good whitefish areas on the American shore, though a few fish are taken regularly at the eastern end of the lake. In the east (Sandy Pond, Selkirk) the fish behave as along the north shore, except that the fishermen do not find them so early. Whitefishing does not begin here until the last of May or early June, possibly because the New York laws have prohibited fishing within 1 mile from shore, within which zone the fish may occur until this date; though it would appear that if this were the case some, at least, would be taken farther out, whither occasional storms would drive them. Along other points on the New York shore (Oswego, Sodus Point, Wilson) whitefish are relatively scarce and of irregular occurrence.

BREEDING HABITS

The time of spawning is said to be November, usually the latter part, continuing sometimes into early December. Specimens collected at Port Hope, Ontario, on November 21, 1917, were nearly ready to spawn.

The best spawning grounds on the lake are in the Bay of Quinte, into which the spawning fish are said to move from the main lake through the Upper Gap. There are also smaller spawning grounds in other parts of the lake, especially along the north shore. Known spawning grounds along the south shore are rare and for the most part have been deserted by the fish latterly (Oak Orchard, Nine-Mile Point). The bottom selected for spawning, the fishermen say, is hard, as in the other lakes, and may be covered by depths of 15 fathoms. Nothing is known of their spawning behavior, except that at Brighton the Quick brothers say the larger fish spawn first.

In some sections the fish appear to mature at small size. The Quick brothers report that fish weighing 2 pounds in the round usually spawn, and that they have seen spawners as small even as 1 pound. Specimens weighing 1 pound in the round, collected in June, 1921, from the Duck Islands, showed no indication of spawning that year, but males taken on August 27, 1923, off Sandy Pond, N. Y., were mature at 1 pound 7 ounces.

ABUNDANCE

On the American shore the whitefish is almost extinct commercially. From 1,064,000 pounds in 1880 the production had fallen to 54,000 pounds in 1922, with no records in excess of 88,000 pounds in the present century. Across the boundary the catch of whitefish has shown a general increase from 1910, which reached its peak only in 1922, when 2,098,000 pounds were reported. The production has been maintained only by an unproportional increase in the quantity of fishing apparatus and has been stimulated by the ever-mounting prices that the markets offer. In most areas on the lake the fishermen believe the whitefish to have become commoner within the last 25 years, and in most ports the species is believed to be holding its own at present.

Genus PROSOPIUM Milner

Milner, in Jordan, 1878, p. 361 (*Coregonus quadrilateralis*).

The Great Lakes fish of the genus are never larger than 5 and usually not more than 2 pounds in weight. The body is subterete, its width equal to about 56 to 68 per cent of its depth. The premaxillaries are wider than long and retrorse in position.

The two openings of each nostril are separated by a single flap. (Fig. 27.) The exposed area of the scales of the lateral line is conspicuously smaller than that of those of the adjacent rows. The gill rakers on the first branchial arch are less than 21 and more than 13; the length of the longest is rarely more than 5 per cent of the head. There are no vestigial teeth. The prefrontal bone is but little developed and does not extend much beyond the anterior edge of the pupil. The cranial carina does not extend to the frontal-parietal suture.

PROSOPIUM QUADRILATERALE Richardson

PILOT, MENOMINEE, ROUND WHITEFISH, FROSTFISH, CISCO, GRAYBACK, CROSS WHITEFISH, LAKE MINNOW (FIG. 30)

Coregonus quadrilateralis Richardson, 1823, pp. 714–716 pl. 25, fig. 2, "small rivers about Fort Enterprise and in the Arctic Sea"; Evermann and Smith, 1896, pp. 296–297, pl. 16, New England to Alaska; Jordan and Evermann, 1911, pp. 38–39, Pl. VII, Alaska and upper Great Lakes to New England.

Prosopium quadrilaterale Dymond, 1926, pp. 54–55, Pl. VIII, fig. 1, Lake Nipigon.

Coregonus nov-angliæ Prescott, 1851, p. 342, Lake Winnepesaukee. Probably also Sea Gwiniad, Pennant, 1792, p. ccxcviii, Hudson Bay.

The species was described from specimens collected in "small rivers about Fort Enterprise and the Arctic Sea." No material from the type locality is available for examination, but there is little doubt that Richardson's description is of a Prosopium of some sort, and it is probable that our Great Lakes forms are very closely related to it. For the present, then, the specific name *quadrilaterale* is retained for them.

The pilot occurs in all the lakes of the Great Lakes series except Erie, and in Lake Nipigon. The representatives of the species in one lake resemble those in another very closely, the differences between them being chiefly such differences as are evident between mature and immature individuals in any one of the lakes. No complete account of the natural history of the species is available for any of the lakes, but such details as are known indicate that the habitat selected is the same throughout the basin; and it is probable, further, that the breeding habits, making due allowance for differences in latitude, which probably affect the time of spawning, are the same. The flesh is not of the best, and the species is of relatively little or no commerical importance anywhere.

Prosopium quadrilaterale of Lake Michigan

The body is subterete, much elongated, little compressed (except at the snout and tail—much less compressed than the whitefish), and uniformly tapered. Its greatest depth is through a point at the front of the dorsal. In adults this measurement is usually about 20 to 22 per cent of the length, though in the largest examples, especially gravid females, it commonly becomes 24 per cent. Owing to the moderate depth of the body, its profiles are gently and uniformly curved. The head is very small and is contained (4.9) 5.2–5.4 (5.6) [81] times in the total length of the body. In side view the outline of the head is roughly ovoid, its dorsal contour curving sharply downward from a point between the orbit and the nares, so that the snout is always

[81] These and succeeding figures, unless otherwise marked, are given for 34 collected specimens ranging from 200 to 419 millimeters in length.

rounded, even in individuals in which the premaxillaries are most retrorse. Its lateral surfaces are nearly flat to a line on a level with the superior edge of the maxillaries and from thence converge sharply in a downward direction, the more sharply as the snout is approached. The dorsal surface of the head is acutely triangular owing to the compression of the entire preorbital and mandibular regions. The width of the head through the nostrils is 17 to 21 per cent of the head length. Its interorbital space is flat or only very faintly convex. A short but heavy median keel runs from a point above the postoculars to a point approximately above the anterior edge of the pupil. A fainter keel originates on each side of it, slightly farther craniad, and extends almost to the nares. The ventral surface of the head is likewise acutely triangular in form but is strongly convex from side to side. The branchiostegal membrane, which has 7 or 8 short rays, is trapezoidal in shape. From it the isthmus narrows distinctly to join the mandible. The premaxillaries are more or less retrorse in position, usually making an angle of 100° to 110° with the horizontal axis of the head. The eye is moderate in proportion to the head, contained (3.9) 4.3–4.6 (5) times in the head length. Its pupil is oval, so that its cranial angle, usually conspicuous in the coregonids, is rounded off. There are (5) 6–7 (8) + (9) 10–11 (12) = (15) 16–18 (19) gill rakers on the first branchial arch. The lateral-line scales run in a nearly straight row and number (84) 87–95 (100).[82] Scale rows[83] around the body, just in front of the dorsal and ventrals, are (40) 42–45 (46); in front of the adipose and the anus, (31) 33–35 (36); and around the caudal peduncle at its commencement, (24) 25–27 (28). There are usually a few scales conspicuously larger than the rest just behind the occiput. The dorsal rays number 11–12 (13);[83] anal rays, 9–11;[83] pectoral rays, 14–16 (17);[83] ventral rays, 10–11.[83] The length of the pectorals is contained (1.8) 1.9–2.2 (2.3) times in the distance from their origin to that of the ventrals. The length of the ventrals is contained 2.1–2.3 (2.5) times in distance from their origin to the anal. (See fig. 12.)

The color in life is silvery, as in the other forms, but in the pilot it is less striking on account of the presence of brighter superficial colorations. The entire dorsal surface, including the cranium, is virtually a uniform bronze to sepia brown tinged with green. The exposed surface of the scales of the back, particularly in the predorsal area, is margined with a band of pigment dots, which tend to obscure the coloration. The sides are brownish; the color is strongest above the lateral line, where it is overlaid by silvery with a pinkish cast. The pinkish cast is brightest below the lateral line, but both the pink and the brown beneath it fade as the colorless belly is approached. The sides of the head are also silvery, with a tinge of bronze, which is strongest in the preorbital region, on the dorsal tip of the operculum, and on the iris. The premaxillaries and tip of the mandible are whitish. The maxillary is spotted with fine dots of brown. The basal half of the paired fins and often of the anal is bright salmon pink. The dorsal fin and the basal half of the shortest and three-fourths of the longest rays of the caudal are brown.

After preservation, all color, including the silvery tone, eventually fades, disclosing further details of pigmentation. Pigment is evident, then, also on the sides

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[82] Sixty-five specimens.

[83] Twelve specimens.

above the lateral line, with a sprinkling of dots down to about the fifth row below. The top of the head and the preorbital area are heavily sprinkled with fine dots, which often collect to form small spots, particularly in the occipital region. Pigment is present on the oculars and on the operculum. The cranial border of the dorsal, the tips of its rays, and the rim of the caudal are washed with smoky. The other fins are usually immaculate, though there are occasionally a few pigment dots on the pectorals and ventrals, particularly on their inner surface.

Pearl organs have been seen on no individuals of the species. Only one adult specimen was taken in the breeding season, and in the case of this specimen (collected on November 19, 1920, out of Michigan City) the epidermal excrescences may have been eliminated by rough treatment subsequent to its capture. It is probable that the development of pearls in the species of Lake Michigan is not different from that in the Lake Huron form.

VARIATIONS

Racial variations.—There are no data available for a discussion of local variations.

Size variations.—An examination of 42 specimens ranging in length between 156 and 210 millimeters, taken in Platte Bay on the Michigan shore, indicates that small individuals have a larger head and eye and somewhat longer paired fins. A comparison of these values for the two classes of specimens follows:

L/H:
- Large fish, (4.9) 5.2–5.4 (5.6).
- Small fish, (4.7) 5–5.1 (5.2).

H/E:
- Large fish, (4.1) 4.3–4.6 (5).
- Small fish, (3.5) 3.7–3.9 (4).

Pv/P:
- Large fish, (1.8) 1.9–2.2 (2.3).
- Small fish, (1.8) 1.9–2 (2.1).

Av/V:
- Large fish, 2.1–2.3 (2.5).
- Small fish, (1.8) 2–2.2 (2.5).

The body depth, of course, is also less, proportionally, in small specimens.

Small individuals in the collection (all those under 200 millimeters and often those up to 230 millimeters) show parr marks. These marks are distinct, roundish, dusky spots 2 to 4 millimeters in diameter, irregularly spaced, separated 2 to 8 millimeters from one another, and scattered more or less at random over the dorsolateral and dorsal surfaces, though there is often an appearance of arrangement in sinuous rows. They are most conspicuous and most numerous on the second to fifth rows of scales above the lateral line and disappear last in this region as the individual grows. Frequently there are dots along the lateral line, also, which are larger and fewer in number than on the rows above it; and there are also fainter marks on the dorsal surface, particularly in the predorsal area. Dymond (1926, Pl. VIII, fig. 1) shows a specimen with these parr marks.

It is noteworthy that of 17 collected specimens between the length of 220 and 300 millimeters, only 4 are sexually mature. They are divided as follows, according to size and sex: Mature—255 female, 267 male, 279 female, and 295 male; immature—220 male, 220 male, 221 male, 226 female, 232 female, 239 male, 242 female, 249 female, 254 female, 256 female, 269 male, 270 female, and 293 female.

The maximum size reported for the lake is about 4 pounds.

GEOGRAPHICAL DISTRIBUTION

Like the blue-backed herring and whitefish, the pilot occurs in schools in suitable localities all along the shores of Lake Michigan. It is fished for even less extensively than the herring, due probably to the fact that it is by no means so abundant nor so easily taken, and consequently complete data on its range and abundance are not available. Unless nets are set for pilots, the numbers of the fish or even their presence may be unsuspected, as they seldom become entangled in the pound or gill nets set for larger fish and are never seen swimming in the open lake. Like the herring, they enter harbors occasionally and may then be taken with hand lines.

R. F. Kleinke, of Menominee, Mich., says there are not now and to his knowledge never were any pilot in Green Bay. At Washington Harbor, Wis., at the mouth of the bay, John Ellafson reports a few taken occasionally both in trout and perch nets. At Sturgeon Bay and at Algoma, Wis., they are taken occasionally in commercial quantities, according to the statement of George Knipfer, who has set nets for these fish. At Port Washington and Milwaukee, Wis., none ever are taken for market but a few are caught in other nets during the year, according to the statement of Delos H. Smith and August B. Budzisz. At Michigan City, Ind., and Grand Haven, Ludington, and Manistee, Mich., the fishermen likewise report the taking of only an occasional pilot. Otto Anderson says he has fished for pilot in the fall out of Arcadia, Mich., and has taken them in commercial quantities. The other ports, all in the State of Michigan, which have at times taken the fish for market are Northport (Hans Anderson and Carl Schrader), Traverse City (Will Hopkins), St. James on Beaver Island (Dennis and Hugh Boyle, James Martin, Robert Gibson, and Hugh Connaghan), and Seul Choix Point (Alex Goudreau).

I have collected specimens from several ports on the lake, all of them casual inclusions with the catches of other species. Data for these are given in Table 96. They are shown platted on the lake chart in Figure 4.

METHOD OF CAPTURE

Unlike the whitefish, the pilot will not follow a lead readily and consequently is taken seldom in the pound or trap nets. Gill nets alone are employed in their capture, therefore, the mesh used ranging between 2½ and 3 inches. Other species, notably herring and perch, also are taken often with the pilot by these nets.

SEASONAL MOVEMENTS

The pilot moves in and off shore like the other shallow-water coregonids. As the species is not sought for regularly, only scattered data on its movements are available.

Data on the occurrence in fall and spring.—Out of Washington Harbor, Sturgeon Bay, Algoma, Arcadia, Northport, Traverse City, St. James, and Seul Choix Point, according to the statements of those fishermen who have attested to the occurrence of the species out of these ports, the pilot can be found inshore on gravel and honeycomb rock in 2 to 6 fathoms in November and often into December, if the weather permits. At this time it is taken frequently in commercial quantities at these ports.

The records in Table 96 show occasional specimens taken in the chub nets on November 19, 1920, 17 miles NNW. and 17½ miles NW. by N. ¾ N. of Michigan City, Ind., in 28 to 32 fathoms, and on March 4, 1921, 15 miles NW. by N. ½ N. of that port in 28 fathoms. Out of Northport pilot are known to occur with the herring in 2 or 3 fathoms for about two weeks when the ice leaves around April 1, but elsewhere no nets are set for pilot in spring, and hence nothing is known of the movements of the species in spring.

Data on the occurrence in summer.—A few fishermen have tried to take the pilot in commercial quantities in the summer. John Ellafson, of Washington Harbor, says that he has taken them in August and September at depths of 6 to 12 fathoms on sand. Otto Anderson, of Arcadia, claims to have found them in 8 to 10 fathoms in September. Robert Gibson, of St. James, says that several years ago, in July and August, in 5 to 8 fathoms on sand and gravel around Garden and Hog Island of the Beaver group, he caught on an average of 500 to 600 pounds of these fish at a lift in 8,000 feet of nets, when lifted after two nights out. In September, Mr. Gibson says, the fish disappeared and could be found neither shallower nor deeper. The other St. James fishermen and Mr. Schrader, of Northport, concur with Mr. Gibson in the assertion that the pilot schools are very erratic in their movements. They visit and leave certain grounds for no apparent reason, and can not be followed in their migrations. Out of Washington Harbor, Northport, Traverse City, and the Beaver Islands an occasional specimen becomes entangled in the trout nets at depths of 6 to 16 fathoms during the summer months.

No individuals have been seen by me or reported by the fishermen from the 1½-inch nets that are set at 30 fathoms out of many ports for bloaters, and none have been seen by me in the chub nets, except those from off Michigan City in 28 to 32 fathoms in November and March, so that the maximum depth to which the species retires is probably about 30 fathoms.

The records indicate, then, that the pilot are found inshore in numbers on honeycomb rock and gravel in November and into December. Little is known of their movements during the remainder of the year, but at one locality, at least, they are found on the beaches again when the ice leaves in the spring. Fishing operations have been conducted for the species out of several ports in July, August, and September, and these operations have disclosed the presence of the species at depths of 5 to 12 fathoms. Casual specimens have been taken out of many ports as deep as 16 fathoms and out of one port as deep as 28 to 32 fathoms, so that 32 fathoms probably marks the upper limit of the depth range of the species.

BREEDING HABITS

The fall inshore movement is for the purpose of spawning. There are no more definite data available than that the fish can be taken abundantly in November and even in December if the weather permits fishing so late. Spawning takes place, according to the fishermen, on honeycomb rock and gravel in 2 to 6 fathoms of water.

FOOD

No studies have been made of the food of the species in Lake Michigan, except that small individuals taken on July 30, 1923, off South Manitou Island were feeding

chiefly on Chironomus larvæ and pupæ. It is probable that its food preferences are similar to those of its relative in Huron. As in Lake Huron, the species is charged with the destruction of trout spawn by virtually every fisherman who is familiar with it, and all these men claim to have seen the trout eggs in the pilot's stomach. Some data on this propensity of the pilot are given on page 552.

COMMERCIAL VALUE

As a food fish the pilot is always rated above the herring, but in this respect it does not even approach the whitefish. The flesh has little fat and spoils readily, so that the pilot nets have to be lifted at short intervals. The fish are sold either fresh or salted.

Prosopium quadrilaterale of Lake Huron

The pilot of Lake Huron differs in few characters from its relative in Lake Michigan. The principal characters capable of numerical expression are compared below:

Gill rakers on the first branchial arch:
- Michigan, (15) 16–18 (19).[84]
- Huron, (15) 16–17 (19).[85]

Lateral-line scales:
- Michigan, (84) 87–95 (100).
- Huron, (80) 84–91 (95).

L/H:
- Michigan, (4.9) 5.2–5.4 (5.6).
- Huron, (4.5) 4.8–5.1 (5.3).

H/E:
- Michigan, (3.9) 4.3–4.6 (5).
- Huron, (4) 4.2–4.5 (4.9).

Pv/P:
- Michigan, (1.8) 1.9–2.2 (2.3).
- Huron, (1.5) 1.8–2 (2.3).

Av/V:
- Michigan, 2.1–2.3 (2.5).
- Huron, (1.8) 2.1–2.2 (2.4).

It appears, thus, that Huron specimens tend to have a proportionally larger head, somewhat longer paired fins, and slightly fewer lateral-line scales. Of course, data are required from many more specimens from both lakes in order to establish the course of the distribution curve for any characters.

The color in life is as in the Michigan form, except that, as a rule, specimens are more heavily pigmented. This character, of course, is most in evidence in alcoholic material. The pigment below the lateral line, besides being more abundant, extends often to the belly. The paired fins often are pigmented distinctly, and frequently there are dots on the anal.

Pearl organs are well developed on males during the breeding season and at least faintly indicated on some females. I have collected no specimens during or immediately previous to the spawning period, and therefore I do not know to what extent nuptial buttons are developed on the two sexes. Pearls were beginning to appear on males taken at the Greater Duck Island on October 18, 1919, were present on males and a few females taken at Wiarton, Ontario, on November 5, 1917, at Kagawong, Ontario, on November 10, 1917, at Alpena, Mich., on November 15, 1919, and in Au Sable River, Mich., in November, 1924. None of these fish were ripe. The maximum development of pearls that I have seem for the species is exhibited by specimen No. 1087 from Wiarton. On this fish they are present on the lateral line and on each scale of the first four rows above and below it. On the fifth

[84] Figures for Michigan, excepting those for scales, are based on an examination of 34 specimens ranging in length from 200 to 419 millimeters. Figures for scales are given for 65 specimens.

[85] Figures for Huron are based on an examination of 72 specimens ranging in length from 200 to 393 millimeters.

and sixth rows above and below they become faint, and their distribution is often discontinuous. There are none on the belly or head and only a few on the back. There is usually only one pearl present on each scale, except on the lateral line, where there are sometimes two. In shape the pearls are rounded, showing faintly a narrow longitudinal thickening, are situated in the center and occupy one-third to one-fourth of the exposed scale surface on the rows bordering the lateral line. They diminish gradually in size dorsad and ventrad. On the lateral line they are less than one-fourth as large as on the adjacent rows and are situated laterad and slightly caudad to the pore.

VARIATIONS

Racial variations.—Specimens are available for comparison from Alpena, Mich., and from the Duck Islands across the lake, but the two groups appear little different in their systematic characters.

Size variations.—The same changes with growth outlined for Lake Michigan specimens seem to obtain in Lake Huron, namely, that small specimens have a larger head and eye, longer paired fins, and less body depth. The figures for specimens under 30 centimeters in length and for those of greater length are compared below for most of these characters:

L/H:
- Large fish, (4.8) 4.9–5.2 (5.3).
- Small fish, (4.5) 4.7–5.1 (5.3).

H/E:
- Large fish, 4.4–4.9.
- Small fish, (3.7) 4–4.3 (4.5).

Pv/P:
- Large fish, (1.8) 1.9–2.1 (2.3).
- Small fish, (1.5) 1.7–2 (2.2).

Av/V:
- Large fish, 2.1–2.3.
- Small fish, (1.9) 2–2.3 (2.4).

Individuals apparently show parr marks in their juvenile stages, which, to judge from the two collected specimens under 20 centimeters in length, are not different from those described for small specimens in Lake Michigan.

None of the collected specimens less than 23 centimeters long are sexually mature, and none over 25 centimeters are immature.

The maximum size reported for the lake is about 4 pounds.

GEOGRAPHICAL DISTRIBUTION

As in Lake Michigan, schools of pilot are to be found in suitable localities all along the shores of Lake Huron. Likewise the species is not sought much in Lake Huron, and therefore the same limitations exist to the securing of data on the occurrence and habits of the species.

On the Canadian shore the pilot seldom is caught for market, but it does occur at other localities in addition to those from which I have collected it, namely, at Tobermory and Providence Bay, according to the statements of Kenneth McLeod and John Purvis. There are other Canadian ports, no doubt, from which it could be caught. On the American shore it is taken not uncommonly, particularly in the fall. It is found in some numbers along the shore from St. Martins Bay to Hammonds Bay, from which area a few are taken to market, both at St. Ignace and Cheboygan. From Hammonds Bay to Middle Island there are said to be none, although in some parts of this area, at least, they have been sought. The Schmekel

brothers, of Rogers, say that they have tried nets at Presque Isle for eight years but never yet have got pilot in them. In the area between Middle Island and Scarecrow Island more pilot are caught than from all the rest of the lake. South of the latter point and in the Saginaw Bay region the fish are rarer again, although about 1902, according to Oscar Hurkett, of Harbor Beach, a heavy run entered the bay. At the south end of the lake between Harbor Beach and Port Huron the species has been, or still is, common. At the former port there has been a marked decrease in its numbers in recent years.

I have collected specimens from many ports on the lake, most of them casual inclusions with the catches of other species. The data for these are given in Table 98. They are shown platted on the chart in Figure 5.

METHOD OF CAPTURE

As in Lake Michigan, the pilot will not follow a lead readily, and consequently it is not taken commonly in the pound or trap nets. In less than 30 fathoms gill nets of 2¾ or 3 inch mesh usually are employed to capture it. At some ports these nets are used for herring, also, and are set most often in the fall.

SEASONAL MOVEMENTS

The pilot moves in and off shore like the other shallow-water coregonids. Few nets suitable for pilot are used in spring, and therefore it is not known when the fish leave the shoals.

Data on occurrence in the fall and spring.—These records are from American waters only. At Cheboygan (according to Louis Peets) and at Middle Island (according to the records of the Alpena and Rogers boats) the schools begin moving into 3 to 5 fathoms about the middle of October on honeycomb rock and gravel. During November the run is at its height. In the spring the Alpena tugs again put their nets on these grounds when navigation opens about April 1. They sometimes get a few lifts of pilot. Bert Andrews, of Port Huron, informs me the pilot came inshore 10 to 12 miles north of Port Huron in 4 fathoms on November 1, 1913. On the 9th and thereafter 4 tons or more were taken in a single lift in 7 to 8 fathoms. The fish gradually retreated northward toward the last of the month. Few are found on these grounds in the spring.

Data on occurrence in summer.—The nets used for other fish in summer are not suitable for pilot, and therefore there are few data on summer occurrence. The pilot are probably at no time in deep water. None ever are taken in the 2¾-inch chub nets in 35 to 50 fathoms off Cheboygan; none were taken in the box of 2¾-inch nets lifted off Alpena from 30 fathoms with a trout gang on September 19, 1917, nor have any ever been reported at any season from the 1½-inch bait nets set at 30 fathoms either at Alpena or Harbor Beach. The identity of the fish is so unmistakable that no fishermen would fail to recognize it when taken. Frank Hebert tells me that off Nine-Mile Point during the first week in September, 1917, a gang of 2¾-inch nets set in 17 to 20 fathoms got 500 pounds of pilot four nights out. On September 2, 1917, I found pilot in the stomachs of trout caught in 20 fathoms. This observation alone has little value in fixing the occurrence of the fish, as there is

nothing to indicate that the pilot were caught in 20 fathoms also, but it need not be ignored when supported by the preceding record. A box (2,250 feet) of nets of 2¾-inch mesh lifted with a whitefish gang in 15 fathoms on September 17, 1917, caught 27 fish of this species. On September 26, 1917, a box of nets in 17 fathoms had 29. On September 24, 1917, a gang set from the can buoy in Thunder Bay to Sulphur Island in 8 to 10 fathoms got 600 pounds three nights out.

Thus all the records indicate that the pilot begin to move inshore in numbers on honeycomb rock and gravel about the middle of October, and that they remain there until the nets are pulled in. Since few gill nets of a mesh suitable for pilot are set in the spring, not much is known about the offshore movement. The depth to which the fish migrate in summer is certainly not over 30 fathoms and probably not over 20. At depths of 10 to 24 fathoms I took specimens off Alpena on September 10, 14, 17, 20, 22, and 26, 1917. Commercial quantities were taken in 1917 at 17 to 20 fathoms the first week of September and in 8 to 10 fathoms on September 24. The inshore movement apparently had already begun on the 24th.

BREEDING HABITS

The inshore movement in fall is for the purpose of spawning. While there are no definite dates available as to when the eggs are deposited, the fishermen say that the run is heaviest during the last two weeks of November, which may indicate that this is the spawning period. The spawning season certainly falls in November, as males taken during the first half of November, 1917, at Kagawong, Gore Bay, Wiarton and Alpena show pearls. They spawn at depths of 4 to 8 fathoms on honeycomb rock and gravel, according to the fishermen. It is interesting to note that the herring spawns at about the same time and at about the same depth; in fact, both fish may be caught in the same nets. The herring are said to spawn on sand and gravel, while the pilot spawns on gravel and honeycomb rock. This leaves gravel as spawning ground common to both. It may be found that the character of the gravel bottom selected by the two species is different and that actually they do not spawn on the same grounds at the same time.

FOOD

An examination of about 50 stomachs collected during October and November, 1917, at Alpena, Mich., and Kagawong, Ontario, shows the main items of food to be Gastropoda, larval and pupal Trichoptera, and larval Ephemeridæ. Adult insects, larval Chironomidæ, Asellus, Cambarus, Bryozoa, plant remains, and sand are included among the articles occasionally ingested.

The pilot is said to eat the spawn of other fish, and probably there is truth in the charge. In fact, almost any fish will eat spawn if it gets a chance, and a fish that feeds habitually on the bottom might be expected to prey heavily on spawn. At least, the fish will eat spawn readily if it is offered them. During the last of October, 1919, pilot were common in 10 feet of water about the docks on the Greater Duck Island. Hooks baited with trout spawn were grabbed instantly. It may be noted in passing that as a game fish the pilot is not to be despised. On one occasion I had an opportunity to determine whether the pilot sought the spawning grounds of other fish. A box (2,250 feet) of 2¾-inch nets was set on October 30, 1917, on the spawning

grounds of the trout 7 miles ENE. of the Alpena can buoy in 15 fathoms. When lifted on November 2 these nets had, among other fish, 41 pilot. The number of pilot caught is not great, but there are reasons, perhaps, why the fish were not abundant. First, the trout had not yet left the grounds, and second, the majority of the pilot were already moving onto their own spawning grounds in 3 to 5 fathoms. Of the 41 fish, 21 had nothing in their stomachs, 12 had trout eggs, and 8 had other food. Thus, 29 per cent of the fish taken are known to have been feeding on trout eggs and 19 per cent were feeding on other things. The remaining 52 per cent may or may not have eaten eggs. The nets had been set for about 48 hours, and if these fish had been caught in the earlier half of this period, there would have been ample time to digest the eggs if they had eaten them. All the fish were alive when taken. The results obtained on this occasion are by no means conclusive, and many more data must be obtained before the pilot can be condemned as a spawn eater.

Prosopium quadrilaterale of Lake Superior

The pilot of Superior agrees in its principal characters rather closely with that of Michigan. The principal characters that can be expressed numerically are compared below:

Gill rakers on the first branchial arch:
- Michigan, (15) 16–18 (19).[86]
- Superior, (15) 16–18 (20).[87]

Lateral-line scales:
- Michigan, (84) 87–95 (100).
- Superior, (84) 86–93 (98).[88]

L/H:
- Michigan, (4.9) 5.2–5.4 (5.6).
- Superior, (4.6) 4.8–5.1 (5.3).

H/E:
- Michigan, (3.9) 4.3–4.6 (5).
- Superior, (4) 4.2–4.6 (5.1).

Pv/P:
- Michigan, (1.8) 1.9–2.2 (2.3).
- Superior, (1.5) 1.7–1.9 (2.1).

Av/V:
- Michigan, 2.1–2.3 (2.5).
- Superior, (1.9) 2–2.2 (2.5).

It appears that the Superior specimens differ from those of Michigan chiefly in having a proportionally longer head and longer paired fins, especially pectorals.

The color in life is like that of Michigan specimens. Fingerlings are less brilliantly colored than adults. A description of these small fish is given under "Size variations." In spirits the coloration averages about as in Huron specimens.

There are indications of pearl organs on both male and female specimens collected on October 1, 1921, at Rossport, Ontario, and it is likely that in the breeding season both sexes are conspicuously pearled, as is known to be the case in the Huron form.

VARIATIONS

Racial variations.—There are no data on local variations.

Size variations.—The depth increases and the head, eye, and ventrals decrease with age, as in the Lake Huron form. For 17 individuals ranging from 65 to 200 millimeters, the L/H ratio is 4.3–4.9 (5.2). This value for the group of specimens less than 300 millimeters and for that of more than 300 millimeters is (4.6) 4.8–5.1 (5.3),

[86] Figures for Michigan, except those for scales, are based on an examination of 34 specimens ranging in length from 200 to 419 millimeters. Lateral-line scales have been counted for 65 specimens.

[87] Figures for Superior are based on an examination of 63 specimens ranging in length from 236 to 387 millimeters.

[88] One specimen with 74.

indicating but little change in the proportion between head length and total length after maturity. The eye decreases more conspicuously in size with age. In specimens 200 millimeters or less in length the H/E ratio ranges from 3.2 to 4.1; in those less than 300 millimeters, (4) 4.1–4.5 (4.6); in those 300 millimeters or over, (4.3) 4.5–5.1. The differences in the Av/V ratio are distinctive only for the group of individuals less than 200 millimeters and for that of the largest fish. The values are (1.7) 1.8–2.1 (2.2) and (1.9) 2–2.2 (2.5), respectively.

The coloration of small specimens is distinctly different from that of adults. The fingerlings (65 to 77 millimeters long) taken at the mouth of the Devils Track River near the international boundary on July 17, 1922, have the back pale sepia with two rows of irregular black spots 1 to 2 millimeters in diameter lying at intervals of less than a diameter close to the median line. Often two spots join and make an elongated patch. The sides are silvery, with a row of black dots much smaller than those on the back lying halfway between the lateral line and the dorsal. These spots also are irregular in size, shape, and spacing. Those in the area anterior to the caudal edge of the dorsal are largest (about 1 millimeter in diameter) and are arranged in a more or less straight line. In the region caudad to this point the spots become smaller and are scattered. At each end of the lateral line lies a conspicuous blackish patch 2 to 3 millimeters in diameter. On the line, spaced at intervals of 2 to 5 millimeters, are found 7 to 10 other patches of similar size and shape. The belly is white. The iris is silvery, tinged with sepia. The paired fins are yellowish, with the yellow of the anal fainter. The ring of pigment around the free edge of the scales of the back characteristic of the adults is very evident.

The spots seem to disappear first on the back. The pigment apparently diffuses over the surface. The dots on the side above the lateral line linger longest and usually split so as to give the appearance of two or three irregular rows. They increase in size as the fish grows but become proportionally smaller until they finally fade. In the specimens 134 to 200 millimeters in length the dorsal spots are paling. In a few mature fish 260 millimeters long there still remain traces of the lateral spotting.

No individuals ranging in size between 200 and 245 millimeters were seen, and these limits are those between the immature and mature fish. The maximum size reported for the lake is about 5 pounds.

GEOGRAPHICAL DISTRIBUTION

I have collected specimens of pilot from Rossport, Black Bay, and Batchawanna on the Canadian shore, from Stannard Rock reef, the Apostle Islands, and from Grand Marais, Minn. Data for these are given in Table 100. They are also shown platted on the chart of the lake in Figure 3. Pilot are known, from the reports of the fishermen, out of Sault Sainte Marie (Will Muntinga), Grand Marais, Mich. (Charles McDonald), Marquette, Mich. (Will Parker), Ontonagon, Mich. (Earl Couture), Gargantua, Ontario (J. A. McMillan), and Michipicoten Island (L. McArthur), and it is probable that the species is distributed generally along the shores of the lake where bottom conditions are suitable.

SEASONAL MOVEMENTS

As on the other lakes, pilot are not caught often for the market, and knowledge of their habits is derived principally from the experience of those fishermen who take the fish for home consumption. Out of Grand Marais, Marquette, on Stannard Rock reef, and Ontonagon in Michigan, Grand Marais, Minn., and Gargantua and Michipicoten Island, Ontario, the fish may be taken in numbers from about November 1 to freezing. At the two latter localities it is reported that they enter the small creeks as early as October and again in early spring. At Grand Marais, Mich., a few are taken under the ice by means of spears. They are known to remain in some abundance on the beaches at this point until July. On Iroquois Shoal above the Sault, Will Muntinga found a few in 15 feet on June 12, 1922. I found them common on July 12, 1922, in a 2¾-inch gill net set from the shore of the South Twin Island, Wis., at a depth of 24 feet. A few were seined off Grand Marais, Minn., also, on July 17 and 18, 1922, and stray specimens were collected from pound nets in Black Bay on July 20, 1922, and out of Rossport on August 10, 1922. As pilot do not enter a pound readily, the taking of only stragglers is no indication of abundance. A few were taken in a 2¾-inch gill net set at Rossport, Ontario, on October 1, 1921, in 24 feet. Numbers were seen around Les Petits Ecrits on October 4, 1921, and off Porphyry Island on September 19, 1923. At these points they could be taken abundantly with a hand line.

It appears, then, that the pilot at no time moves far from the beaches. It is likely that the shallow water on the shores of Lake Superior does not often become too warm for the fish.

BREEDING HABITS

Little is known of the breeding habits of the species. Will Parker informs me that when he fishes herring from November 10 to December 1 on the grounds between Partridge Island and Toneys Point and Sachs Head he gets pilot on the gravel bottom and herring on the sand. Earl Couture says the fish spawn out of Ontonagon from the last of November into December on gravel near shore. Out of Grand Marais, Minn., the fish spawn during December, according to James Scott, at the mouth of Cascade River and at the mouth of the Devils Track River. The bottom selected is bowlders and gravel along the shore. It is not known that the fish spawn when they run into the creeks around Gargantua and on Michipicoten Island in the fall, but no doubt they do.

Prosopium quadrilaterale of Lake Nipigon

Two specimens collected off the mouth of Blackwater River on July 29, 1922, in 10 to 20 feet of water on gravel bottom are not different in their characters from specimens from the Great Lakes. The individuals taken measure 191 and 318 millimeters. Both are females, the smaller one immature. Gill rakers, $7+10$ and $9+10$; lateral-line scales, 89 and 95; L/H, 4.7 and 5; H/E, 4.2 and 4.4; Pv/P, 1.8 and 1.9; Av/V, 2 and 2.2.

Little is known of the distribution or habits of the pilot in the lake. The fishermen never get them in their whitefish nets, it appears, and no nets of smaller mesh

are employed. Dymond (1926) says pilot usually are found at depths of less than 40 feet and that they prefer the shallow northern bays and the mouth of rivers.

Prosopium quadrilaterale of Lake Ontario

Only six specimens, ranging in length between 213 and 361 millimeters, have been seen from Lake Ontario, and these do not differ from those of other lakes. The gill rakers in five number 17, in one 18; the lateral-line scales range between 86 and 93; L/H values range between 4.9 and 5.5; H/E, between 4 and 4.8; Pv/P, between 1.7 and 2; and Av/V, between 2.2 and 2.4. The smallest example shows several distinct "parr marks" on the caudal peduncle.

The maximum size reported for the lake is about 4 pounds.

GEOGRAPHICAL DISTRIBUTION

Few pilot are caught for the market, and virtually all of these are taken from ports on the north shore of the lake. At Port Hope and Coburg, Ontario, the species formerly was and still is abundant, according to T. J. McMahon, and at Brighton, Ontario, Harry and W. A. Quick say it is found in commercial numbers. D. M. Wheeler, of Wilson, N. Y., says that pilot were common in the early days off Braddocks Point, a report recently confirmed by H. A. Donovan, of Charlotte, N. Y. At Bronte and Burlington, Ontario, and Wilson, Sodus Point, and Selkirk, N. Y., a few specimens are taken occasionally, so that every fisherman is acquainted with the appearance of the species. A specimen was seen at Port Hope, Ontario, on November 23, 1917; two were collected at Winona, Ontario, on November 23, 1917; two at Brighton, Ontario, on June 6 and 18, 1922; one at Sandy Pond, N. Y., on August 24, 1923; and one was obtained from the collection of the University of Toronto.

SEASONAL MOVEMENTS

On account of the commercial insignificance of the pilot the fishermen know little about its habits. The Quick brothers, of Brighton, say that the fish travel in schools and that these schools are very erratic in their movements, so that netters have difficulty in following them. They are on the beaches during the winter and up to June, according to Messrs. Quick, and thereafter they occur at depths of 6 to 16 fathoms, where they are caught occasionally in the whitefish nets. At Wilson stray individuals are caught at times in the 3-inch herring nets, which are set in spring and fall in 50 to 75 feet.

No data are at hand on the breeding habits of the species.

Table 1.—*Localities from which data and specimens were obtained on Lakes Superior and Nipigon. Where ports were visited, the amount of time spent at each and the number of commercial and special lifts examined are given*

Location	Dates	Number of specimens collected									Lifts examined			
		nipigon	zenithicus	reighardi	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Special	Whitefish	Herring	Bloaters
LAKE SUPERIOR														
Grand Marais, Mich	Oct. 3–4, 1917		52		25	6		4						
Marquette, Mich	Aug. 2–12, 1921		184		47	15	28	21	16		2	1	1	1
Ontonagon, Mich	Aug. 13–30, 1921		112	5	2		39	12	16		2			
Grand Marais, Minn	Sept. 1–21, 1921		40	2	3		30				1			
Rossport, Ontario	Sept. 24–Oct. 8, 1921		42		23		2	7		17	1		1	
Sault Ste. Marie, Mich	June 8–18, 1922		88		2		1	17	13	1	1	1		
Michipicoten Island, Ontario	June 18–23, 1922		62		22			4			1	1		
Coppermine Point, Ontario	June 24–July 7, 1922		78		28	1		7	3		1	1		
South Twin Island, Wis	July 10–15, 1922		211	2	4	5	199	1	1	31	2			
Duluth, Minn	July 15–16, 1922													
Grand Marais, Minn	July 17–18, 1922		21		1		12	[1] 600		[1] 17				
Port Arthur, Ontario	July 19–21, 1922			3				12	34	5		1		
Rossport, Ontario	Aug. 3–10, 1922			14				31	13	3		2		
Port Arthur, Ontario	Sept. 13–21, 1923		68	111			35	12		1	5			
Rossport, Ontario	Sept. 21–Oct. 2, 1923		26	9			2	7	8	8	3			
Marquette, Mich	Feb, 8, 1921 [2]							15	1					
	Nov. 22–Dec. 5, 1922 [2]		100			52								
	1923 [2]		1		10	1								
	November, 1925 [2]		2			1		5						
Rossport, Ontario	Mar. 10, 1922 [2]			1				62						
Duluth, Minn	July 17, 1922 [2]		500	2	2		2	2						
Port Arthur, Ontario	Nov. 25, 1922 [2]			199				12						
Stannard Rock, Mich	August, 1923 [2]									1				
Port Coldwell, Ontario	Oct. 22, 1923 [2]		1		5									
LAKE NIPIGON														
Macdiarmid, Ontario	July 21–Aug. 3, 1922	14	128	66	143		77	17	31	2	4	3		
	Oct. 26, 1922 [2]	1	5	5	5		17	2						

[1] Fingerlings caught with seine. [2] Additional specimens received from other collectors.

Table 2.—*Localities from which data and specimens were obtained on Lake Michigan. Where ports were visited, the amount of time spent at each and the number of commercial lifts examined are given*

Location	Dates	Number of specimens collected										Lifts examined			
		johannæ	alpenæ	zenithicus	reighardi	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Chub	Whitefish	Herring	Bloaters
Petoskey, Mich	July 14, 1917									2			1		
Charlevoix, Mich	do												1		
St. Ignace, Mich	July 15–17, 1917									[1] 2	[1] 3				
Grand Haven, Mich	Mar. 19–22, 1919	10	7	3	7	5	12	161				2			
Milwaukee, Wis	Mar. 22–25, 1919			3	2	5		69	9			2		1	
Northport, Mich	June 22–24, 1920	1	18		56	4		70	4	4		1	1		1
Traverse City, Mich	June 24–25, 1920								13	13	3		1	1	
St. James, Mich	June 26–28, 1920									18	3		1		
Charlevoix, Mich	June 28–30, 1920	1	8	2	11	1	6	78				1			
Manistique, Mich	Aug. 10–13, 1920	1	6	1	6	1	1	50	11			1			
Menominee, Mich	Aug. 13–17, 1920							34	20					3	
Washington Harbor, Wis	Aug. 17–20, 1920	11	4		14	2	22	103	52		1	1		2	
Sturgeon Bay, Wis	Aug. 20–24, 1920	5		2	3	1	20	19				1			
Algoma, Wis	Aug. 24, 1920	1	1	2	16		6	24				1			
Manistee, Mich	Aug. 27–28, 1920				4		1	12	2		2			1	
Ludington, Mich	Aug. 28–30, 1920	13			1	4	23	56				1			
Muskegon, Mich	Aug. 31, 1920								1						
Michigan City, Ind	Sept. 2–5, 1920	4	9	11	4	1	4	24	8			1			
Milwaukee, Wis	Sept. 21–24, 1920	2	1	14	2	2	5	45	4			2			
Port Washington, Wis	Sept. 24–27, 1920	3	2	9	6	2	8	56	11	4		1		1	1
Sheboygan, Wis	Sept. 27–Oct. 2, 1920	2	2	12	48		12	120				2			1

[1] Taken near Epoufette, Mich.

TABLE 2.—*Localities from which data and specimens were obtained on Lake Michigan. Where ports were visited, the amount of time spent at each and the number of commercial lifts examined are given*—Continued

Location	Dates	Number of specimen scollected										Lifts examined			
		johannæ	alpenæ	zenithicus	reighardi	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Chub	Whitefish	Herring	Bloaters
Frankfort, Mich	Oct. 2–5, 1920	1	5	2	5	1	7	37				1			
Racine, Wis	Oct. 7–9, 1920														1
Michigan City, Ind	Oct. 9–12, 1920		3	5	15		2	13				1			
	Nov. 7–9, 1920		4	11	7		1	12				1			
Milwaukee, Wis	Nov. 12–16, 1920		4	15				12	5	11	2	2			
Oconto, Wis	Nov. 17, 1920								34					2	
Michigan City, Ind	Nov. 18–22, 1920		17	19	8			51			3	3			
	Mar. 2–4, 1921			3	11			24	9	4	1	2			1
Traverse City, Mich	July 17–20, 1923								14	21		(2)			1
Platte Bay, Mich	July 21–23, 1923		2					8	13		42	(2)			
Traverse City, Mich	July 24–26, 1923		1		3			3	43	1		(2)			
South Manitou Island, Mich	July 28–31, 1923		3						1	22	4	(2)	1		
Charlevoix, Mich	Aug. 10–11, 1923	1	4		35	3	7	1		1		2			
Seul Choix Point, Mich	Aug. 20, 1920 [3]								7	15					
Michigan City, Ind	Apr. 1, 1921 [3]			2	47			2							
Port Washington, Wis	May 26, 1922 [3]	1		2	8	5	1	1							
Northport, Mich	July 31, 1923 [3]	15	156	5	94	13	36	43	4						
Charlevoix, Mich	June 15, 1923 [3]		50		10										
	Aug. 21, 1923 [3]		52		3			1							
	May 3, 1924 [3]		4		43										

[2] Specimens also taken by seines and special gill nets. [3] Additional specimens received from other collectors.

TABLE 3.—*Localities from which data and specimens were obtained on Lake Huron. Where ports were visited, the amount of time spent at each and the number of commercial lifts examined are given*

Location	Dates	Numbe 1of specimens collected									Lifts examined			
		johannæ	alpenæ	zenithicus	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Chub	Whitefish	Herring	Bloaters
St. Ignace, Mich	July 15–17, 1917							11	1	4		1	1	
Cheboygan, Mich	July 21–24, 1917	11	12	11	1		16		2	1	1	1		
Rogers, Mich	July 24, 1917	18	9	5	3				3		1			
Alpena, Mich	Aug. 11–14, 1917	13	19	2	10		10	11	4		1		1	
	Sept. 1–27, 1917	90	51	55	13	96	306	47	55	12	10	4	5	1
Cheboygan, Mich	Sept. 27–Oct. 2, 1917	2	3	11			20	7			2			
Blind River, Ontario	Oct. 5–10, 1917									6				
Cheboygan, Mich	Oct. 11–12, 1917													
Rogers, Mich	Oct. 13–14, 1917		5	11			31	2			1			
Alpena, Mich	Oct. 14–21, 1917	5	4	5	12	5					2	1		
East Tawas, Mich	Oct. 21–22, 1917							27	16			1	1	
Bay City, Mich	Oct. 22–25, 1917							26	15			1	2	
Port Huron, Mich	Oct. 25–26, 1917													
Harbor Beach, Mich	Oct. 26–29, 1917	15	13	3	1		26				1			
Southampton, Ontario	Nov. 3–5, 1917													
Wiarton, Ontario	Nov. 5–6, 1917	4	14	1	2			15	1	6	1	1	1	
Blind River, Ontario	Nov. 7–8, 1917							6						
Cutler, Ontario	Nov. 8–9, 1917													
Kagawong, Ontario	Nov. 9–10, 1917							3	4	3		1		
Gore Bay, Ontario	Nov. 10–13, 1917							2	4	2				
Cutler, Ontario	Nov. 11, 1917							20					1	
Gore Bay, Ontario	Nov. 12, 1917								3					
Cheboygan, Mich	Nov. 13–14, 1917													
Alpena, Mich	Nov. 14–16, 1917											1		
Wiarton, Ontario	July 26–29, 1919	6	30		4	1	76	6	6		1		1	
Lions Head, Ontario	July 29–31, 1919	13	28	2	5	2	43				1			
Alpena, Mich	Aug. 24–Sept. 19, 1919	39	2	5	4	31	102				5	3		2
Cheboygan, Mich	Sept. 19–22, 1919													
Gore Bay, Ontario	Sept. 23–29, 1919								10			1		
Providence Bay, Ontario	Sept. 29–Oct. 1, 1919								2					
Tobermory, Ontario	Oct. 1–3, 1919							3						
Lions Head, Ontario	Oct. 3–6, 1919	8	6		10	2	52				1			

TABLE 3—*Localities from which data and specimens were obtained on Lake Huron. Where ports were visited, the amount of time spent at each and the number of commercial lifts examined are given.*—Continued

Location	Dates	Number of specimens collected									Lifts examined			
		johannæ	alpenæ	zenithicus	nigripinnis	kiyi	hoyi	artedi	clupeaformis	quadrilaterale	Chub	Whitefish	Herring	Bloaters
Killarney, Ontario	Oct. 8–15, 1919							41	16	1		2		
Kagawong, Ontario	Oct. 15–16, 1919							1	7	2		1		
Gore Bay, Ontario	Oct. 17, 1919													
Duck Islands, Ontario	Oct. 18–26, 1919							12	7	34		1		
Wiarton, Ontario	Nov. 26–Dec. 4, 1919		14				32	15	2		4			
Alpena, Mich	Aug. 7, 1920										1			
	June 28–July 10, 1923	37	43	16	19	80	32				5	2		
Alpena, Mich	Nov. 2, 1917 [1]							13		41				
	Nov. 15, 1919 [1]							18		40				
Harbor Beach, Mich	Dec. 9, 1917 [1]							11						
	do [1]						25							
	Mar. 15, 1919 [1]		46	30			92	1						
Hammond Bay, Mich	Sept. 28, 1919 [1]								8					
Cheboygan, Mich	Oct. 15, 1919 [1]		42	12			44							
Bay City, Mich	Oct.–Nov., 1921 [1]		1					300						
	November, 1922 [1]							500						
	November, 1924 [1]							250						
	Nov. 25, 1925 [1]		3											
Oscoda, Mich	Nov. 2, 1922 [1]							362						
Wiarton, Ontario	June 10, 1922 [1]	25	25		100									
	June 26, 1923 [1]	25	100		25									

[1] Additional specimens received from other collections.

TABLE 4.—*Localities from which data and specimens were obtained on Lakes Erie and Ontario. Where ports were visited, the amount of time spent at each and the number of commercial and special lifts examined are given*

Location	Dates	Number of specimens collected						Lifts examined		
		rei-ghardi	kiyi	hoyi	artedi	clupea-formis	quadri-laterale	Special nets	Herring	White-fish
LAKE ONTARIO										
Port Hope, Ontario	Nov. 21, 1917					4				1
Brighton, Ontario	Nov. 22, 1917				12				1	
Bronte, Ontario	Nov. 23, 1917				16	2			1	
Winona, Ontario	do			1	12	2	2		1	
Brighton, Ontario	June 5–6, 1921						1			1
Cape Vincent, N. Y	June 7, 1921				12	16			1	1
Brighton, Ontario	June 10–11, 1921	18	1	16	4			1		2
	June 16–20, 1921	16		12		3	1	1		1
Wilson, N. Y	June 21–26, 1921	2	18	28				2		
Bronte, Ontario	June 27–30, 1921		7	10	6	2		1		2
Charlotte, N. Y	July 1–6, 1921	1	31	58	1			1		
Selkirk, N. Y	July 7–11, 1921	4	2	10	28	1			1	1
Sodus Point, N. Y	July 12–13, 1921	3	27	74				1	1	
Wilson, N. Y	July 14–21, 1921	10	36	15	39			3		
Sandy Pond, N. Y	Aug. 23–31, 1923	23	1	20	60	8	1	1	1	1
Oswego, N. Y	Sept. 1–5 1923	1	12	13	5			1	1	
LAKE ERIE										
Ashtabula, Ohio	Oct. J–23, 1920				8	2				1
Erie, Pa	Oct. 24–26, 1920				75	4			5	5
Dunkirk, N. Y	Oct. 27–28, 1920				59				4	
Toledo, Ohio	Nov. 27, 1920					3				1
Sandusky, Ohio	Nov. 28–29, 1920				19	5			1	2
Westfield, N. Y	July 21, 1921								1	
Merlin, Ontario	Nov. 22–24, 1924								1	1
Erieau, Ontario	Nov. 24–25, 1924								1	
Ridgetown, Ontario	Nov. 25–26, 1924									1
Port Stanley, Ontario	Nov. 26, 1924									
Monroe, Mich	1920 [1]				12	2				
Port Stanley, Ontario	December, 1922 [1]				62					
Erieau, Ontario	December, 1924 [1]				25					

[1] Other collectors.

TABLE 5.—*Distribution of the species of Coregonidæ in the larger lakes of the Laurentian Basin*

Species	Nipigon	Superior	Michigan	Huron	Erie	Ontario
Leucichthys johannæ			×	×		
L. alpenæ			×	×		
L. zenithicus	×	×	×	×		
L. reighardi	×	×	×			×
L. nigripinnis	×	×	×	×		×
L. kiyi		×	×	×		×
L. hoyi	×	×	×	×		×
L. artedi	×	×	×	×	×	×
L. nipigon	×					
Coregonus clupeaformis	×	×	×	×	×	×
Prosopium quadrilaterale	×	×	×	×		×

TABLE 6.—*Frequency distribution of the total number of gill rakers on the first branchial arch for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the tops of the columns are classes of gill-raker numbers; entries below these are numbers of individuals in each class; entries in the last column are the number of specimens of each form included in the table]

Species and lake	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Johannæ:																		
Michigan												1	11	18	20	26	15	14
Huron											4	18	42	91	122	82	49	19
Alpenæ:																		
Huron																	3	15
Zenithicus:																		
Superior																		1
Huron																		4
Reighardi:																		
Nipigon																		8
Superior																		3
Michigan																1	1	10
Clupeaformis:																		
Nipigon												1	6	11	11	4		
Superior											2	24	34	32	15	2		
Michigan										1	9	44	43	42	11	1		
Huron										1	20	44	55	49	18	4	2	
Erie											3	18	21	36	20	2		
Ontario											1	5	13	10	4	2	1	
Quadrilaterale:																		
Nipigon			1		1													
Superior	4	12	28	14	4	1												
Michigan	4	5	10	6	1													
Huron	6	22	25	11	3													
Ontario			5	1														

Species and lake	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Johannæ:																	
Michigan	9	6	1	1													
Huron	9	4	1														
Alpenæ:																	
Michigan	1	8	15	26	31	47	47	60	54	41	29	14	4	6			
Huron	32	38	47	55	40	37	52	34	21	10	2	1					
Zenithicus:																	
Nipigon	2	1	13	19	35	36	38	9	3	4							
Superior	1	2	10	27	59	72	115	182	171	132	72	27	8	4			
Michigan			2	4	5	20	31	19	17	13	7	4					
Huron	3	9	16	17	28	29	19	23	7		1	1					
Reighardi:																	
Nipigon	13	17	35	15	8	1											
Superior	11	31	44	52	43	25	12	6	5	2							
Michigan	25	46	73	87	63	45	26	14	7	5	3						
Ontario	2	8	14	20	13	11	1	4	2	1							
Nigripinnis:																	
Nipigon												4	5	9	13	37	37
Superior				1	6	17	18	46	33	15	7	5	2	1		1	
Michigan									1	1		4	4	7	8	9	5
Huron								2	1	3	1	14	10	20	29	19	9
Kiyi:																	
Superior				3	8	11	13	23	7	7	3	1	1				
Michigan		2	7	20	41	42	37	32	22	6	1	1	1				
Huron		1	8	24	51	47	30	25	14	7	4	1					
Ontario									7	10	22	21	27	15	14	4	

TABLE 6.—*Frequency distribution of the total number of gill rakers on the first branchial arch for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Hoyi:																	
Nipigon								6	12	26	19	41	28	23	5	2	
Superior					1	11	15	28	74	63	68	36	24	8	2		1
Michigan					3	17	31	99	160	218	226	174	107	44	18	3	
Huron					8	33	72	138	202	194	134	63	15	9	2		
Ontario							1	2	8	25	35	48	33	45	36	4	5
Artedi:																	
Nipigon									1	1		2	4	10	14	11	14
Superior						1			1	1	7	21	37	37	48	48	23
Michigan									1	2	7	18	24	46	57	62	49
Huron								1	1	4	10	17	38	47	57	42	36
Erie									2	5	23	32	37	56	58	40	41
Ontario									3	3	7	11	15	24	28	26	23

Species and lake	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	Total
Johannæ:																		
Michigan																		122
Huron																		441
Alpenæ:																		
Michigan																		383
Huron																		417
Zenithicus:																		
Nipigon																		160
Superior																		883
Michigan																		122
Huron																		157
Reighardi:																		
Nipigon																		97
Superior																		234
Michigan																		406
Ontario																		76
Nigripinnis:																		
Nipigon	49	32	12	11	4													213
Superior																		152
Michigan	6	5	3															53
Huron	12	7	2															129
Kiyi:																		
Superior																		77
Michigan																		212
Huron																		212
Ontario																		120
Hoyi:																		
Nipigon																		162
Superior																		331
Michigan																		1, 100
Huron																		870
Ontario	1																	243
Artedi:																		
Nipigon	5	6	2	1														71
Superior	13	4	4	3														248
Michigan	37	44	22	14	4	4												391
Huron	31	11	6	1														302
Erie	13	3	1	2														313
Ontario	24	11	8	7	1													191
Nipigon:																		
Nipigon					3	4	10	5	1	7	2	2	2	0	1	1	1	39
Clupeaformis:																		
Nipigon																		33
Superior																		109
Michigan																		151
Huron																		193
Erie																		100
Ontario																		36
Quadrilaterale:																		
Nipigon																		2
Superior																		63
Michigan																		26
Huron																		67
Ontario																		6

Table 7.—*Frequency distribution of the number of scales in the lateral line for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the tops of the columns indicate the classes of scale numbers; entries below these show the number of individuals of each form, by classes; in the last column is given the number of individuals of each form included in the table]

Species and lake	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81
Johannæ:																						
Michigan															1			2	3	2	3	11
Huron								1						4	2	11	6	17	18	9	37	34
Alpenæ:																						
Michigan												2	2	1	9	12	13	14	20	32	33	36
Huron											2	4	5	9	12	16	33	28	29	39	39	40
Zenithicus:																						
Nipigon							1	2	4	8	13	10	16	11	21	16	16	17	7		3	
Superior										5	3	7	13	26	38	58	75	84	100	102	126	95
Michigan											3	2	4	2	4	11	11	11	11	13	17	14
Huron											1	4	10	6	14	17	10	18	13	13	11	11
Reighardi:																						
Nipigon					1	1	7	5	8	7	15	10	12	7	5	2	3	3				
Superior						1	2	9	9	10	15	23	25	29	29	17	20	18	6	7	7	5
Michigan							1	1	3	9	10	13	25	29	32	33	38	37	34	27	29	24
Ontario							1					4	3	3	9	10	10	1	11	2	6	3
Nigripinnis:																						
Nipigon							2	1	1	8	16	19	21	17	26	21	17	14	10	3	6	1
Superior														1		2	4	4	8	10	15	15
Michigan															1		3	1	1	2	9	8
Huron													3	3	2	6	6	11	16	12	13	8
Kiyi:																						
Superior													1	2	2	4	8	7	11	8	12	6
Michigan												1	1	2	3		5	8	10	16	19	12
Huron											2	3	5	6	8	14	20	17	19	19	35	18
Ontario												1		1	4	1	7	15	9	13	14	14
Hoyi:																						
Nipigon							1		1	3	5	8	7	9	20	13	17	13	13	12	13	7
Superior						1	5	14	14	22	26	22	32	38	28	34	36	17	20	7	10	3
Michigan	1		2	6	5	17	21	48	41	88	107	97	142	134	116	94	82	52	36	16	13	11
Huron				1	1	11	16	18	47	53	84	64	95	80	94	85	48	33	26	21	5	10
Ontario				1	1	3	4	11	15	15	23	26	34	24	29	26	16	5	8	5	1	1
Artedi:																						
Nipigon						1			3	4	5	9	7	6	10	6	8	3	4	3	2	1
Superior													1	1	3	3	4	5	3	8	8	7
Michigan									1			1	1	3	2	6	13	15	15	19	24	40
Huron									1	1	1	3	4	3	9	7	13	16	11	20	23	23
Erie					1		2	3	6	17	22	35	48	64	80	76	97	74	66	47	35	31
Ontario							1		3	1	11	8	6	17	26	25	23	31	19	15	26	17
Nipigon: Nipigon									1	1		2	4	2	6	7	2	8	0	1	1	3
Clupeaformis:																						
Nipigon																	1	2	3	3	1	3
Superior																		3	4	7	8	6
Michigan															1	1	1	3	2	7	7	17
Huron														2	1	1	1	4	6	10	13	13
Erie														2	3	8	6	18	19	24	42	44
Ontario																1	3	1	6	9	13	13
Quadrilaterale:																						
Superior															1							
Huron																					1	

Species and lake	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	105	Total
Johannæ:																					
Michigan	3	7	8	8	5	4	6	4	4	1	1			1							74
Huron	27	16	12	20	16	12	7	6	2	1											258
Alpenæ:																					
Michigan	37	35	26	21	13	11	8	1	1	0	1				1						329
Huron	17	27	11	1	5	3			2	1											323
Zenithicus:																					
Nipigon	1	1																			147
Superior	78	48	44	24	13	7	7	1	2												956
Michigan	7	9	6	5	4	4	1			1											140
Huron	6	3	4		1	1	1														144
Reighardi:																					
Nipigon																					86
Superior		1																			233
Michigan	9	13	10	4	5	5	1		2						1						395
Ontario	2	2		1	1																69
Nigripinnis:																					
Nipigon																					183
Superior	15	20	13	19	14	6	6	5	2	3											162
Michigan	2	3	5	4	6	3	1	2													51
Huron	8	11	2	6	1	2	1														111

TABLE 7.—*Frequency distribution of the number of scales in the lateral line for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	105	Total
Kiyi:																					
Superior	2	3	6	3	2	1															78
Michigan	21	21	14	12	8	8	4	2	3	1											171
Huron	12	14	4	5	3	1	1	1													207
Ontario	11	15	6	5	6	6	2	1		1											132
Hoyi:																					
Nipigon	2	1		1																	146
Superior	2	1	1																		333
Michigan	3	1	1																		1,134
Huron	2	1	1																		796
Ontario	1																				249
Artedi:																					
Nipigon																					72
Superior	8	8	18	12	17	20	19	14	18	17	16	15	7	5	6	6	1	1	1	1	253
Michigan	37	38	29	40	24	20	13	14	5	4	2	4	1								371
Huron	31	29	34	17	14	13	9	10	9	3		1	1	1			1				308
Erie	14	12	9	7	2		1	1													750
Ontario	15	9	4	5	2		1	1													266
Nipigon: Nipigon	2																				40
Clupeaformis:																					
Nipigon	3	4	2	5	1	3	1	2													34
Superior	15	14	14	9	12	2	5	3	2	2	0	0	1								107
Michigan	12	17	16	23	29	18	14	9	5	5	2	2									191
Huron	18	14	21	26	18	13	9	8	13	4											195
Erie	38	30	25	16	15	13	6	5	6	3		1									324
Ontario	23	21	34	17	16	11	14	5	6	3	2										198
Quadrilaterale:																					
Nipigon								1						1							2
Superior			1	1	7	12	3	9	8	7	5	6	1	4	1	2	1				69
Michigan			1	1		4	6	8	5	4	10	6	3	6	4	2	2	2	1		65
Huron	2	1	5	8	2	8	10	12	6	4	1	1		3							64
Ontario					1	1		1			1	2									6

TABLE 8.—*Frequency distribution of the ratio between the length of the body and the length of the head (L/H) for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the top of the columns indicate the classes of ratios; entries beneath these are the numbers of each form, by classes; numbers in the last column give, for each group, the total numbers of specimens included in the table. The various species in each lake often are divided into two size groups. The numbers expressing millimeters, given after the name of the lake, indicate, when preceded by a plus (+) sign, the lower length limit of specimens of the group; when preceded by a minus (−) sign, the upper length limit]

Species and lake	Length, in millimeters	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5
Johannæ:													
Michigan	+200					5	7	17	23	12	8	1	
Huron	+200	1	1	5	11	30	54	65	31	10	1		
	−200			1	17	32	31	15	1	1			
Alpenæ:													
Michigan	+210					3	3	12	61	63	87	45	15
	−210						1	5	4	3	1		
Huron	+210			1	1	7	16	27	43	40	21	8	
	−210	1		3	10	44	69	46	24	3			
Zenithicus:													
Nipigon	+200		2	3	19	36	42	30	8	2			
	−200			1		7	3	2	1				
Superior	+200			3	32	111	178	221	157	31	11	1	
	−200		4	9	26	36	41	40	13	4			
Michigan	+200						6	17	24	36	22	6	3
	−200							6	3	1			
Huron	+200						9	10	23	18	16	8	1
	−200				1	6	4	22	25	14	4	1	
Reighardi:													
Nipigon	+200		3	5	24	20	16	10	1				
	−200			3	3	6	1						
Superior	+200				1	19	50	88	45	22	5	2	
Michigan	+200						1	8	36	73	74	56	32
	−200							6	15	22	32	19	7
Ontario	+200							1		1	7	6	25
Nigripinnis:													
Nipigon	+200			1	5	30	41	60	56	21	3	2	
	−200			2			1						
Superior	+200				1	4	23	42	53	21	13	3	
Michigan	+200					1		3	10	10	12	10	3
Huron	+200				2	3	12	35	34	27	11	6	

TABLE 8.—*Frequency distribution of the ratio between the length of the body and the length of the head (L/H) for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	Length, in millimeters	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	4.5
Kiyi:													
Superior	−200		3	8	27	15	13	10	1				
Michigan	+200				4	18	31	34	28	7	3		
	−200					8	12	17	6	1			
Huron	+200					7	9	4					
	−200		13	35	55	50	24	9	4				
Ontario [1]						2	5	11	44	43	19	7	
Hoyi:													
Nipigon [2]				10	15	35	37	50	23	4			
Superior [2]		1	2	16	52	76	88	59	28	6	3		
Michigan	+200						3	13	32	43	26	16	5
	−200			4	33	53	135	269	212	197	73	25	9
Huron	−200		1	10	59	105	155	264	164	68	38	6	3
Ontario [1]					1	4	15	56	69	61	29	14	4
Artedi:													
Nipigon	+225					1		3	3	3	2	1	
	−225						1	5	11	19	19	6	6
Superior	+225								6	8	21	35	53
	−225							2	3	11	12	12	15
Michigan	+225								1	13	25	35	32
	−225							5	14	30	36	32	21
Huron	+225						1	8	13	19	24	36	49
	−225							4	10	24	34	28	22
Erie	+225								1	4	15	20	35
	−225						1	5	10	30	40	26	8
Ontario	+225				1			0	3	18	29	37	44
	−225						3	1	5	7	11	15	5
Nipigon:													
Nipigon	+200					2	11	14	10	3	1	0	1
Clupeaformis: [1]													
Nipigon									1		9	10	7
Superior												4	14
Michigan										2	5	14	18
Huron								1		1	1	2	17
Ontario												2	4
Quadrilaterale:													
Nipigon	+200												
Superior	+200												
	−200										2	3	2
Michigan	+200												
	−200												
Huron	+200												1
Ontario	+200												1

Species and lake	4.6	4.7	4.8	4.9	5	5.1	5.2	5.3	5.4	5.5	5.6	Total
Johannæ:												
Michigan												73
Huron												209
												98
Alpenæ:												
Michigan	1											290
												14
Huron												164
												200
Zenithicus:												
Nipigon												141
												14
Superior												745
												173
Michigan												114
												10
Huron												85
												77
Reighardi:												
Nipigon												79
												13
Superior												232
Michigan	17	3	1									301
	1											102
Ontario	18	14	3		1							75

[1] Mostly specimens over 200 millimeters long.
[2] Mostly specimens under 200 millimeters long.

TABLE 8.—*Frequency distribution of the ratio between the length of the body and the length of the head (L/H) for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	4.6	4.7	4.8	4.9	5	5.1	5.2	5.3	5.4	5.5	5.6	Total
Nigripinnis:												
Nipigon												219
												3
Superior												160
Michigan	1	1										51
Huron												130
Kiyi:												
Superior												77
Michigan												125
												44
Huron												20
												190
Ontario [1]												131
Hoyi:												
Nipigon [2]												174
Superior [2]												331
Michigan	1											139
												1,010
Huron												873
Ontario [1]	1											254
Artedi:												
Nipigon												13
	1											68
Superior	37	11	5	1	2	2						181
	14	1	1									71
Michigan	15	10	5		2							138
	8											146
Huron	34	14	6	2	1							207
	9	1	1									133
Erie	31	26	13	4	5		1					155
	3	2										125
Ontario	31	28	5	1	1							198
	2											50
Nipigon:												
Nipigon												42
Clupeaformis: [1]												
Nipigon	4	2	1									34
Superior	27	28	21	11	4							109
Michigan	22	18	27	8	4	2	3	1				124
Huron	28	55	46	21	19	1						192
Erie		5	5	2	5			1				18
Ontario	6	6	8	8	3	1	1					39
Quadrilaterale:												
Nipigon		1			1							2
Superior	1	1	11	14	15	14	3	3				62
	3		2	3	1		1					17
Michigan				1	4	5	5	7	7	4	1	34
		2	4	3	20	8	2					39
Huron	4	7	11	8	16	14	7	4				72
Ontario				1	1		2			1		6

[1] Mostly specimens over 200 millimeters long. [2] Mostly specimens under 200 millimeters long.

TABLE 9.—*Frequency distribution of the ratio between the length of the head and the diameter of the eye (H/E) for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the top of the columns indicate the classes of ratios; entries beneath these are the numbers of each form, by classes; numbers in the last column give, for each group, the total numbers of specimens included in the table. The various species in each lake often are divided into two size groups. The numbers expressing millimeters, given after the name of the lake, indicate, when preceded by a plus (+) sign, the lower length limit of specimens of the group; when preceded by a minus (−) sign, the upper length limit]

Species and lake	Length, in millimeters	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3
Johannæ:														
Michigan	+200										1	5	4	9
Huron	+200									1	2	9	15	20
	−200						1	1	2	6	15	23	23	13
Alpenæ:														
Michigan	+210								1	1	5	8	37	40
	−210							1	2	0	2	3	4	3
Huron	+210										4	2	7	5
	−210						5	8	30	41	55	33	19	11

TABLE 9.—*Frequency distribution of the ratio between the length of the head and the diameter of the eye (H/E) for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	Length, in millimeters	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3
Zenithicus:														
Nipigon	+200						1			7	16	30	32	19
	−200						1		1		1	5	1	
Superior	+200									6	22	35	88	112
	−200						10	16	31	48	40	17	7	2
Michigan	+200										3	4	21	33
	−200								1		3	2	4	
Huron	+200									2	4	4	15	16
	−200					3	6	13	5	9	17	8	7	1
Reighardi:														
Nipigon	+200						1	1	5	6	17	8	7	7
	−200							5	4	6				
Superior	+200						1	4	9	35	68	49	43	16
Michigan	+200						1	4	19	49	93	50	51	22
	−200					2	19	25	25	11	15	3	1	1
Ontario	+200										9	8	20	14
Nigripinnis:														
Nipigon	+200					1	19	32	48	44	39	32	6	5
	−200		1	1	1				1					
Superior	+200										1	2	18	32
Michigan	+200										5	8	13	13
Huron	+200						1	1	4	16	41	33	17	11
Kiyi:														
Superior	−200				2	13	17	22	14	7	2	1		
Michigan	+200						2	1	14	14	51	19	17	8
	−200						1	3	16	14	7	3		
Huron	+200							2	2	4	5	2	2	3
	−200			1	8	22	43	48	37	19	10			
Ontario	(1)						1	3	5	15	46	34	18	9
Hoyi:														
Nipigon	(2)	1	1	1	2	18	29	36	46	25	12	1	2	
Superior	(2)		1	1	13	39	61	108	49	30	24	3	2	1
Michigan	+200								7	22	57	24	16	8
	−200			1	4	22	81	188	297	199	152	39	9	
Huron	(2)			5	24	94	187	224	188	85	50	6	2	
Ontario	(1)							3	3	7	27	35	58	60
Artedi:														
Nipigon	+225							1		4	7	1		
	−225					1	6	19	16	10	14	3		
Superior	+225						1		4	3	15	22	28	27
	−225				1	2	3	4	2	5	14	15	19	7
Michigan	+225						1	1	2	13	37	33	26	11
	−225					3	7	17	28	30	36	13	8	1
Huron	+225				1			17	17	21	46	37	21	22
	−225						2	17	24	25	29	15	10	7
Erie	+225								1		8	16	24	22
	−225							2	9	24	42	26	12	7
Ontario	+225									5	16	18	39	30
	−225								3	4	8	12	12	5
Nipigon: Nipigon	+200								1		1	1	7	2
Clupeaformis:[1]														
Nipigon										4	5	2	6	5
Superior									1		1	4	10	19
Michigan									3	5	15	9	7	14
Huron									1		7	11	15	15
Erie														2
Ontario												1	4	2
Quadrilaterale:														
Nipigon	+200												1	
Superior	+200										2	6	14	6
	−200		1	4	3	4	0	1	1	1	1	1		
Michigan	+200									7		1	1	3
	−200					2	4	11	10	8	3			
Huron	+200										10	8	12	6
Ontario	+200										1			1

[1] Mostly specimens over 200 millimeters long. [2] Mostly specimens under 200 millimeters long.

TABLE 9.—*Frequency distribution of the ratio between the length of the head and the diameter of the eye (H/E) for each of the 11 species of Coregonidæ in the Great Lakes*—Continued

Species and lake	4.4	4.5	4.6	4.7	4.8	4.9	5	5.1	5.2	5.3	5.4	Total
Johannæ:												
Michigan	16	20	6	9	2	1						73
Huron	37	45	17	16	17	8	7	2	1	1		208
	5	2										98
Alpenæ:												
Michigan	53	66	33	23	8	5	3	2	2			271
												15
Huron	7	21	24	40	18	16	14		1			159
	2											204
Zenithicus:												
Nipigon	21	7	2									135
												9
Superior	149	147	110	52	23	10	2	2				758
	1	1										173
Michigan	25	16	7	1			1					111
												10
Huron	19	9	7	6				1	1			84
												69
Reighardi:												
Nipigon	12	3	1		1							69
												15
Superior	4	1	1				1					232
Michigan	7	3	2									301
												102
Ontario	12	5	4	1	1	1	1					76
Nigripinnis:												
Nipigon												226
												4
Superior	36	24	18	18	7		3		1			162
Michigan	7	2	3									51
Huron	2	2	2									130
Kiyi:												
Superior												78
Michigan												126
												44
Huron												18
												188
Ontario	1											132
Hoyi:												
Nipigon												174
Superior												332
Michigan	3	1										138
												992
Huron												865
Ontario	29	22	9	2								255
Artedi:												
Nipigon												13
												69
Superior	36	15	11	7	2	4		2				177
	4	1										77
Michigan	3	4	4	1								136
												143
Huron	9	2	2	3				1				198
												129
Erie	21	25	13	14	7	3						154
	1											124
Ontario	30	19	13	5	3	1						179
	2											46
Nipigon: Nipigon	6	3	7	3	5	3	2		1			42
Clupeaformis: [1]												
Nipigon	2	4		3	3							34
Superior	26	20	14	9	4		1					109
Michigan	13	11	8	10	13	10	6					124
Huron	17	27	19	20	15	12	21	5	4	5		194
Erie		1	3		3	4	3	1	1			18
Ontario	5	5	3	4	3	2	6	3		1		39
Quadrilaterale:												
Nipigon	1											2
Superior	8	10	8	3		2	2	2				63
												17
Michigan	3	8	3	1		1	2					30
												38
Huron	6	7	6	6	3	3						67
Ontario		1	2		1							6

TABLE 10.—*Frequency distribution of the ratio between the length of the pectoral and the pectoral-ventral distance (PV/P) for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the top of the column indicate the classes of ratios; entries beneath these are the numbers of each form, by classes; numbers in the last column give, for each group, the total numbers of specimens included in the table. The various species in each lake often are divided into two size groups. The numbers expressing millimeters, given after the name of the lake, indicate, when preceded by a plus (+) sign, the lower length limit of specimens of the group; when preceded by a minus (−) sign, the upper length limit]

Species and lake	Length, in millimeters	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	Total
Johannæ:																					
Michigan	+200					10	13	16	23	6	4	2									74
Huron	+200			3	9	32	53	60	27	15	5	1									205
	−200		1	2	10	34	22	12	2	2	3										88
Alpenæ:																					
Michigan	+210						2	6	19	43	68	66	43	24	2	2					275
	−210						1	1		7	1	3	1								14
Huron	+210						2	14	30	38	37	25	7	1							154
	−210						4	23	40	42	48	22	4	1	1						185
Zenithicus:																					
Nipigon	+200					11	29	26	33	21	8	2									130
	−200					1	5	7													13
Superior	+200			1	1	26	94	178	220	123	80	20	5	2	1						751
	−200				1	7	12	20	34	33	36	14	8	4	1						170
Michigan	+200							3	8	11	28	28	24	6	3		1				112
	−200									2	5	1									8
Huron	+200						2	2	10	18	27	16	5	2							82
	−200							2	8	9	18	15	13	5	1	1	1				73
Reighardi:																					
Nipigon	+200				7	2	20	21	11	6	1										68
	−200					3	7	2	4												16
Superior	+200					4	8	26	49	57	56	22	7	2	2						233
Michigan	+200							2	4	4	38	64	61	58	34	18	11	2	1		297
	−200					1			3	4	16	19	14	19	8	2	2	1			89
Ontario	+200							1		1	2	3	14	12	14	10	7	2	1	2	69
Nigripinnis:																					
Nipigon	+200		2	17	34	67	47	13		1											181
	−200				1	2															3
Superior	+200				1	17	41	47	36	11	6	2	1								162
Michigan	+200					3	18	11	8	4	4		1								49
Huron	+200		2	6	24	35	31	19	6	2											125
Kiyi:																					
Superior	−200	1	10	15	24	20	6	2													78
Michigan	+200	1		5	10	31	29	28	10	7	5	1									126
	−200			1	9	13	13	5													41
Huron	+200	1		1	3	8	4	3													20
	−200		3	14	35	59	39	19	6	3											178
Ontario [1]						1	3	18	32	26	26	10	4								120
Hoyi:																					
Nipigon [2]			1	8	27	42	52	34	2	2											168
Superior [2]					23	55	74	85	53	27	10	1	1								329
Michigan	+200						6	8	23	34	34	16	7	6							134
	−200			1	3	15	76	153	236	194	146	51	19	6	1	3					904
Huron [2]					6	25	84	174	218	136	121	45	6								815
Ontario [1]					5	11	26	48	63	37	36	17	3								246
Artedi:																					
Nipigon	+225						2	7	4												13
	−225					3	13	23	18	5	4										66
Superior	+225							4	6	18	38	43	39	19	6	4	3		1		181
	−225						2	5	11	6	19	9	15	4							71
Michigan	+225						1	2	5	24	35	24	24	14	4	5	1				139
	−225						3	5	20	23	57	21	10	1		1					141
Huron	+225					1	9	12	13	20	47	43	31	17	2	5	2				202
	−225							4	13	23	40	29	12	6							127
Erie	+225						2	12	21	26	37	25	17	8	6	3					157
	−225						8	17	37	30	25	4	1								122
Ontario	+225							4	21	32	60	38	19	12	3	1					190
	−225						3	3	13	15	12	3	1								50
Nipigon:																					
Nipigon	+200				1	10	9	15	7	1											43
Clupeaformis: [1]																					
Nipigon						4	13	7	6	3	1										34
Superior					3	7	22	21	23	13	9	6	3	2							109
Michigan						3	13	23	20	26	23	7	5	1							121
Huron						2	11	26	43	43	35	15	1								176
Erie							1	3	4	9	1										18
Ontario					1	2	1	5	9	11	6	3	1								39
Quadrilaterale:																					
Nipigon	+200								1	1											2
Superior	+200					3	3	16	21	9	8	2									62
	−200								5	4	3	1									13
Michigan	+200								1	4	7	10	3	1							26
	−200								6	17	15	4									42
Huron	+200					1	2	7	19	13	22	3	1	1							69
Ontario	+200							1	2	2	1										6

[1] Mostly specimens over 200 millimeters long.

[2] Mostly specimens under 200 millimeters long.

TABLE 11.—*Frequency distribution of the ratio between the length of the ventral and the ventral-anal distance (AV/V) for each of the 11 species of Coregonidæ in the Great Lakes*

[Numbers at the top of the columns indicate the classes of ratios; entries beneath these are the numbers of each form, by classes; numbers in the last column give, for each group, the total number of specimens included in the table. The various species in each lake often are divided into two size groups. The numbers expressing millimeters, given after the name of the lake, indicates when preceded by a plus (+) sign, the lower length limit of specimens of the group; when preceded by a minus (—) sign, the upper length limit]

Species and lake	Length, in millimeters	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2	2.1	2.2	2.3	2.4	2.5	Total
Johannæ:																				
Michigan	+200				2	12	13	25	15	5										72
Huron	+200			1	7	35	58	42	13	6										162
	−200	1		1	3	24	17	7	2	1										56
Alpenæ:																				
Michigan	+210					3	12	38	70	73	56	18	4							274
	−210							3	4	4	2									13
Huron	+210						8	32	31	28	32	9	3							143
	−210				2	7	34	63	35	6	2									149
Zenithicus:																				
Nipigon	+200				1	8	31	39	32	13	5									129
	−200					1	5	6	2											14
Superior	+200			1		18	106	234	253	95	16	1	1							725
	−200			3	12	16	32	33	16	2	1									115
Michigan	+200					2	9	30	27	33	11	3		1						116
	−200					1	4	1	3	1										10
Huron	+200					2	5	8	26	18	6	1								66
	−200				1	3	18	24	12	13	2									73
Reighardi:																				
Nipigon	+200				1	1	12	22	19	12	1									68
	−200						2	9	5											16
Superior	+200					2	11	42	67	63	40	7	1							233
Michigan	+200					5	20	47	99	85	30	10	1							297
	−200					3	12	25	32	16	4	1								93
Ontario	+200						1	6	16	29	16	2	2	2	1					75
Nigripinnis:																				
Nipigon	+200				2	24	43	67	20	10	3									169
	−200				1	1	1													3
Superior	+200				1	19	40	37	34	7	2									140
Michigan	+200					9	11	15	10	4										49
Huron	+200			2	13	33	40	12	8	1										109
Kiyi:																				
Superior	−200		1	23	34	15	5	1												79
Michigan	+200		1	16	51	33	23	3												127
	−200			9	23	8	3													43
Huron	+200			1	7	1	3													12
	−200		2	38	86	56	8	2												192
Ontario [1]				1	8	32	37	31	8	1										118
Hoyi:																				
Nipigon [2]				12	36	65	31	4	1											149
Superior [2]			1	24	84	101	84	31	4	1										330
Michigan	+200				1	14	38	47	21	11	1									133
	−200			4	70	267	354	234	54	9										992
Huron [2]				5	75	247	256	193	64	10	1									851
Ontario [1]					8	29	40	62	72	16										227
Artedi:																				
Nipigon	+225							5	4	3	1									13
	−225						2	8	22	27	6									65
Superior	+225						1	0	15	43	53	38	17	8	2		1			178
	−225							3	10	22	14	10	5							64
Michigan	+225							1	13	18	48	31	13	8		2	1			135
	−225						2	7	27	50	37	11	5	1						140
Huron	+225				1	1	7	9	16	31	60	51	11	6	1					194
	−225						1	2	17	41	38	21	7							127
Erie	+225							6	28	35	33	16	16	8	2					144
	−225						7	32	40	28	2	3								112
Ontario	+225						2	8	44	51	42	33	9	5						194
	−225					1	2	12	19	8	6									48
Nipigon:																				
Nipigon	+200						2	12	17	7	3									41
Clupeaformis: [1]																				
Nipigon						1	1	2	13	12	5									34
Superior							1	3	24	36	28	15	2							109
Michigan							2	4	32	40	22	16	8	2						126
Huron								3	25	60	54	33	12	1						188
Erie								1	2	10	3	1								17
Ontario							1	3	4	14	9	7	1							39
Quadrilaterale:																				
Nipigon	+200													1		1				2
Superior	+200												4	19	14	17	5	1	2	62
	−200										1	3	1	6	4	1				16
Michigan	+200														6	7	12	2	1	28
	−200														13	12	3			28
Huron [1]												2	3	10	16	21	10	4		66
Ontario	+200															2	1	1		4

[1] Mostly specimens over 200 millimeters long.

[2] Mostly specimens under 200 millimeters long.

TABLE 12.—*Temperature readings of the waters of Lakes Nipigon, Michigan, and Huron*

Record No.	Location	Date	Time	Depth, in fathoms	Temperature, ° C.
	NIPIGON				
1	2½ miles south of Livingston Point	July 28, 1922	10 a. m.	(1)	16.2
2	do	do		5	14.9
3	do	do		10	10
4	do	do		12	7.8
5	do	do		15	5.9
6	do	do		20	5.2
7	do	do		25	4.9
8	do	do		40	4.4
9	do	do		(2) 56	4
10	Off Blackwater River	do	5 p. m.	(1)	19.5
	MICHIGAN				
11	Green Bay, 8 miles south of Green Island	Aug. 14, 1920		(1)	19
12	do	do		(2) 16	10.9
13	Green Bay, 4 miles west of Boyer Bluff	Aug. 18, 1920		(1)	18.9
14	do	do		(2) 24	6.3
15	10 miles E. by N. of Algoma, Wis	Aug. 24, 1920		31	5.1
16	do	do		49	4.2
17	20 miles N. by W. ¾ W. of Michigan City, Ind	Oct. 11, 1920		(1)	16.8
18	do	do		40	4.2
	HURON				
19	30 miles east of Alpena	Sept. 12, 1917		(2) 65	4
20	11½ miles SE. by S. from Alpena can buoy	Sept. 17, 1917		(1)	14
21	do	do		(2) 15	10.3
22	14 miles N. by E. of Thunder Bay Island	Sept. 18, 1919		(2) 60	4
23	16 miles northeast of Cheboygan	Sept. 29, 1917		(1)	11.8
24	22 miles SE. by E. ½ E. from the can buoy, Alpena	Sept. 13, 1919		(1)	15.6
25	do	do		(2) 35	5.4
26	6 miles NNE. of Thunder Bay	Nov. 16, 1917		(1)	5.6
27	do	do		(2) 8	5.6

[1] Surface. [2] Bottom.

TABLE 13.—*Temperature readings of the waters of Lake Superior*

Record No.	Location	Date	Time	Depth, fathoms	Temperature, ° C.
1	7 miles WNW. of Point Iroquois Light	June 14, 1922	4 p. m.	(1)	7.7
2	do	do		(2) 25	4
3	6 miles northeast off east end light of Michipicoten Island	June 19, 1922	9 a. m	(1)	3
4	do	do		20	3.6
5	do	do	2 p. m.	(1)	4
6	Below Leach Island	June 23, 1922		(1)	3.5
7	12 miles off Coppermine Point	June 26, 1922	8.30 a. m.	(1)	6.4
8	12 miles off Alona Bay	do	12 m.	(1)	3.8
9	Black Bay, off Demers Point	July 20, 1922	2 p. m.	(1)	14.4
10	do	do		(2) 8	12.9
11	South of Thunder Cape Light	do	4.30 p. m.	(1)	8.5
12	Off Crow Point	Aug. 5, 1922	10 a. m.	(1)	12.4
13	do	Aug. 10, 1922	9 a. m.	(1)	12.1
14	Simpson Channel	Aug. 5, 1922	10.30 a. m.	(1)	16.3
15	do	do	4.45 p. m.	5	6.6
16	do	do		10	5
17	do	Aug. 10, 1922	10.30 a. m.	(1)	15.8
18	Morn Point	Aug. 5, 1922	4.15 p. m.	(1)	15.4
19	do	Aug. 10, 1922	5.30 p. m.	(1)	14.2
20	Armour Harbor	Aug. 5, 1922	1.15 p. m.	(1)	15
21	do	Aug. 10, 1922	2.30 p. m.	(1)	14.6
22	do	do		(2) 4	9.8
23	Moffat Strait	Aug. 5, 1922	11.15 a. m.	(1)	16.3
24	do	Aug. 10, 1922	12.30 p. m.	(1)	15.2
25	do	do		(2) 4	9.7
26	21 miles west of Ontonagon, Mich	Aug. 24, 1921		(1)	18.1
27	do	do		54	4
28	6 miles NNW. of Ontonagon, Mich	Aug. 25, 1921		34	5

[1] Surface. [2] Bottom.

TABLE 14.—*Total weight of chubs taken by each of five tugs on Lake Huron, the number of lifts of the gill nets, and the average weight of each lift, for each month of the fishing season*

Locality and date	Total weight	Number of lifts	Average weight per lift	Locality and date	Total weight	Number of lifts	Average weight per lift
Cheboygan, Mich., 1915:	*Pounds*		*Pounds*	Duck Islands, Ontario, 1915:	*Pounds*		*Pounds*
May	8,510	6	1,418	May	4,470	3	1,490
June	21,980	13	1,690	June	22,920	12	1,910
July	26,258	24	1,094	July	36,610	18	2,034
August	29,010	22	1,318	August	13,553	8	1,694
September	64,655	24	2,693	Southampton, Ontario, 1917:			
October [1]	31,200	14	2,228	May	4,620	2	2,310
Alpena, Mich., 1915:				June	12,565	7	1,795
April	41,325	23	1,796	July	9,075	7	1,296
May	33,755	23	1,467	August	9,475	9	1,052
June	43,305	18	2,405	September	5,910	7	844
July	45,225	22	2,055	Harbor Beach, Mich., 1916:			
August	46,275	19	2,435	June	4,870	2	2,435
September	29,790	24	1,241	July	21,263	10	2,126
October	18,485	15	1,232	August	30,910	13	2,377
November	32,930	15	2,195	September	18,405	9	2,045
December	8,780	4	2,195	October	27,740	14	1,981

[1] Nothing after Oct. 20.

TABLE 15.—*Total weight of chubs taken by each of three tugs on Lake Michigan, the number of lifts of the gill nets, and the average weight of each lift, for each month of the fishing season*

Locality and date	Total weight	Number of lifts	Average weight per lift	Locality and date	Total weight	Number of lifts	Average weight per lift
Charlevoix, Mich., 1914:	*Pounds*		*Pounds*	Northport, Mich., 1916—Con.	*Pounds*		*Pounds*
May	6,023	14	430	October	8,435	18	468
June	10,753	18	597	November	29,532	20	1,476
July	12,657	22	575	December	14,190	13	1,091
August	14,846	22	674	Michigan City, Ind., 1917:			
September	13,293	23	577	March	4,600	5	920
October	14,428	19	758	April	14,200	11	1,290
November	5,496	11	499	May	18,000	13	1,380
December	5,578	11	507	June	19,550	22	860
Northport, Mich., 1916:				July	40,200	23	1,740
April	5,520	10	552	August	64,700	27	2,390
May	11,799	23	513	September	40,400	21	1,920
June	2,620	8	327	October	59,200	17	3,480
September	9,842	20	492	November	63,400	21	3,010

TABLE 16.—*Records of the occurrence of Leucichthys johannæ in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of johannæ	Preserved specimens examined: +200	Preserved specimens examined: −200
Washington Harbor, Wis.	1	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay, mud	900	30	11	------
Sturgeon Bay, Wis.	2	Aug. 23, 1920	12 miles E. by S. of ship channel mouth.	2⅝, 2¾	60–70	Mud	50	22	4	1
Algoma, Wis.	3	Aug. 24, 1920	10 miles E. by N.	2½	35–50	Gravel, mud.	310	(1)	1	------
Sheboygan, Wis.	4	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	(2)	2	------
Port Washington, Wis.	5	Sept. 25, 1920	18 miles E. ½ S.	2½	65–48	do	285	(1)	3	------
	6	May 26, 1922	24 miles E. by N.	3½	60–80	Mud	------	(2)	1	------
Milwaukee, Wis.	7	Sept. 23, 1920	27 miles ESE.	2½	60	Red clay	250	(1)	2	------
Michigan City, Ind.	8	Sept. 31, 1920	22 miles NW. by N. ½ N.	2½	30–40	Clay	------	(1)	4	------
	9	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Clay, mud	535	(1)	------	------
Grand Haven, Mich.	10	Mar. 20, 1919	12 miles west	2¾	50–55	Clay	------	(2)	9	1
Ludington, Mich.	11	Aug. 30, 1920	17 miles W. ½ S.	2¾	60–70	do	------	(2)	8	------
	12	do	12 miles W. ½ S.	2¾	45–50	do	------	(2)	5	------
Frankfort, Mich.	13	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	7	1	------
Northport, Mich.	14	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40–60	Mud	200	(1)	1	------
	15	July 31, 1923	do	2¾	40–60	do	------	(1)	15	------
Charlevoix, Mich.	16	June 29, 1920	5 miles N. by E.	2¾	40–55	Clay, mud	------	(1)	1	------
	17	Aug. 11, 1923	3 miles NW. ½ W.	2¾	35–60	Red clay	375	(1)	1	------
Manistique, Mich.	18	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70	------	200	(1)	1	------
Racine, Wis.[3]	------	------	------	------	------	------	------	------	1	------
Sturgeon Bay, Wis.[3]	------	------	------	------	------	------	------	------	3	------

[1] Rare. [2] Lift not examined or percentage not ascertained. [3] Wisconsin Geological Survey collection, borrowed specimens.

TABLE 17.—*Numerical expressions of certain systematic characters for the type of Leucichthys johannæ and for nine other specimens from Lake Michigan, selected according to size and locality*

Field No.	Locality	Length, millimeters	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
87353[1]	Racine, Wis.	265	10+19	♂	82	4.2	5.8	9.1	8.4	2.7	8.0	3.6	7.7	2.1	2.2	3.0	3.2
1570	Grand Haven, Mich.	254	11+18	♂	81	4.1	5.6	8.4	8.2	2.7	7.6	3.6	7.2	2.0	2.0	2.8	3.0
1593	do	280	12+18	♂	88	4.3	5.9	10.1	10.3	2.8	7.3	4.2	7.7	1.8	2.1	2.9	3.3
2949	Manistique, Mich.	265	11+17	♂	87	4.0	5.4	8.8	9.6	2.7	6.9	3.9	8.2	2.0	2.0	2.8	3.0
3218	Washington Harbor, Wis.	268	11+19	♂	85	4.1	5.8	8.9	8.7	2.8	7.2	3.7	7.4	2.0	2.0	2.8	3.1
3292	Sturgeon Bay, Wis.	245	12+20	♂	91	4.2	5.6	9.8	9.7	2.7	7.0	4.3	8.4	1.9	2.1	2.8	3.2
3301	do	231	12+20	♀	84	4.1	5.5	8.8	8.8	2.7	8.1	4.0	7.7	1.9	2.0	2.7	3.1
3402	Ludington, Mich.	262	10+20	♀	83	4.2	5.9	9.7	8.7	2.7	7.1	3.9	8.7	2.2	2.1	2.9	3.2
3471	do	288	11+17	♀	87	4.0	5.4	9.3	8.4	3.0	9.2	3.8	7.7	2.0	2.0	2.7	3.1
3668	Port Washington, Wis.	252	10+17	♀	82	4.2	5.7	9.4	9.0	2.8	9.1	3.8	8.4	2.1	2.0	2.8	3.1

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
87353[1]	Racine, Wis.	4.5	4.5	2.5	3.4	2.0	3.4	6.7	3.3	1.8	2.6	2.0	1.5	10	12	11	17	1.6	0.87	9
1570	Grand Haven, Mich.	4.1	4.5	2.7	3.5	2.0	3.3	6.8	3.3	2.0	2.5	1.6	1.2	10	14	12	17	1.4	.89	9
1593	do	4.5	4.8	2.8	3.8	2.1	3.4	6.0	3.4	2.0	2.7	1.7	1.4	10	11	11	15	1.4	1.0	8
2949	Manistique, Mich.	4.1	4.4	2.7	3.4	1.9	3.6	6.0	3.2	2.0	2.5	1.6	1.2	10	11	12	17	1.4	1.0	8
3218	Washington Harbor, Wis.	4.4	4.6	2.6	3.6	2.0	3.6	7.2	3.2	1.8	2.5	1.7	1.3	11	12	12	17	1.5	.94	8
3292	Sturgeon Bay, Wis.	4.3	4.4	2.7	3.5	2.0	3.0	6.4	3.3	2.0	2.6	1.8	1.3	9	11	11	17	1.6	1.0	9
3301	do	4.2	4.3	2.8	3.6	2.0	4.3	6.0	3.2	2.1	2.7	1.6	1.3	10	11	12	17	1.5	.98	8
3402	Ludington, Mich.	4.5	4.6	2.6	3.5	2.0	3.3	7.8	3.3	1.9	2.5	1.8	1.5	10	16	12	20	1.5	.88	9
3471	do	4.3	4.8	2.7	3.7	2.0	4.1	6.4	3.5	2.0	2.7	1.7	1.5	11	13	11	15	1.5	.82	9
3668	Port Washington, Wis.	4.3	4.6	2.7	3.5	2.0	3.7	6.0	3.3	2.0	2.5	1.8	1.4	10	14	11	16	1.5	.91	8

[1] Type: U. S. National Museum number.

TABLE 18.—*Records of the occurrence of Leucichthys johannæ in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined	
									+200 mm.	−200 mm.
Lake Huron proper:										
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef.	2¾	35–50	Clay		(1)	10	1
	2	Sept. 29, 1917	2 miles northeast of Spectacle Reef.	2¾	35–50	do	1,850	(2)	1	
	3	Oct. 1, 1917		2¾						1
Rogers, Mich.	4	July 24, 1917		2¾	60–70	Clay		(1)	18	
	5	Oct. 14, 1917	12 miles E. by N. ½ N.	2¾	35–50	do	1,500	(2)		
Alpena, Mich.	6	Aug. 13, 1917	38 miles east of can buoy	2¾	70–80	do	1,470	(1)	12	1
	7	Sept. 7, 1917	26 miles SE. by E. ¼ E. of can buoy.	4½	16–20			(2)	1	
	8	do	Center of lake, east of can buoy.	2¾	70–80	Clay	3,250	50	5	1
	9	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30			(2)		1
	10	Sept. 10, 1917	Center of lake, northeast of can buoy.	2¾	60–70	Clay	1,300	80		
	11	Sept. 12, 1917	Center of lake, east of can buoy.	2¾	65–80	do	2,610	60	2	2
	12	Sept. 14, 1917	Center of lake, northeast of can buoy.	2¾	65–80	do	1,200	80		2
	13	Sept. 17, 1917	do	2¾	60–70	do		75	2	
	14	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60	do	825	(1)	9	11
	15	Sept. 19, 1917	Center of lake, northeast of can buoy.	2¾	65–80	do		(1)	3	6
	16	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65	do		(1)	3	5
	17	Sept. 21, 1917	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–75	do		(1)	3	10
	18	do	Center of lake, east of can buoy.	2¾	65–70	do		42	14	8
	19	Sept. 24, 1917	do	2¾	65–80	do		30		
	20	Sept. 26, 1917	do	2¾	65–80	do		60	2	
	21	Oct. 17, 1917	do	2¾	65–80	do		50	1	
	22	Oct. 20, 1917	do	2¾	65–80	do		40	4	
	23	Aug. 30, 1919	18 miles N. by E. ½ E. of Thunder Bay Island.	2¾	60–64	do		53		
	24	Sept. 3, 1919	28 miles E. ¼ S. of can buoy	2¾	60–64	do		53		
	25	Sept. 18, 1919	14 miles N. by E. of Thunder Bay Island.	2¾	65	do		(1)		5
	26	do		2¾				(1)	14	20
	27	Aug. 7, 1920	19 miles NE. ½ N. of Thunder Bay Island.	2¾	60–65		3,500	90		
	28	June 28, 1923	19 miles northeast of Thunder Bay Island.	2¾	60–70		2,100	20		
	29	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–70	Clay	1,600	63	8	4
	30	July 2, 1923	20 miles E. by N. of can buoy	2¾	60–70	do	2,000	12	3	
	31	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80–100	do	6,000	8	10	1
	32	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60	do	1,400	47	10	1
Harbor Beach, Mich.	33	Oct. 27, 1917	35 miles NE. by N. ¾ N. of city.	2¾	50	do	1,183	50	15	
Georgian Bay:										
Lion's Head, Ontario.	34	July 30, 1919	21 miles east of Surprise Shoal.	3	60	Mud	400	50	12	1
	35	Oct. 6, 1919	Off White Bluff	3	70	do	425	(4)	8	
Wiarton, Ontario.	36	Nov. 6, 1917	6½ miles northeast of Griffith Island.	3	45–60	do		(1)	4	
	37	July 28, 1919	Off Cape Croker	3	52	do	500	50	6	
	38	June 10, 1922	do	3				(1)	8	
	39	June 26, 1923	do	3				(1)	24	
Borrowed specimens:										
Detour, Mich.[3]									1	

[1] Lift not examined or percentage not ascertained.
[2] Rare.
[3] Field Museum collection.
[4] Few.

TABLE 19.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys johannæ from Lake Huron, 10 of them more than 200 millimeters long and 10 less than 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	51	Cheboygan, Mich.	245	♂	11+19	80	3.8	5.4	10.2	9.6	2.7	8.0	4.0	8.0	2.0	1.9	2.6
	79	Rogers, Mich.	257	Im. ♀	10+16	83	4.1	5.8	9.5	8.6	2.8	9.4	4.0	8.0	1.9	2.0	2.8
	86	do	262	♀	10+18	82	4.0	5.8	9.8	8.9	2.7	8.7	3.9	8.8	2.1	1.9	2.7
	90	do	250	♀	11+18	80	4.2	5.8	10.0	9.2	2.7	8.0	4.2	8.4	2.0	2.0	2.7
	140	Alpena, Mich.	281	♀	11+17	87	4.0	5.7	9.6	9.0	2.7	7.8	3.6	7.0	1.9	1.9	2.7
	150	do	260	♀	11+18	85	4.1	5.9	9.9	9.0	2.8	8.1	4.2	8.5	2.0	2.0	2.9
	201	do	254	♂	11+19	83	4.0	5.7	9.4	8.4	2.8	8.2	4.2	8.0	1.9	1.9	2.7
	773	do	256	♀	12+19	82	4.2	5.9	9.6	9.7	2.8	8.2	4.3	8.0	1.8	2.1	2.9
	777	do	282	♀	11+18	88	4.1	5.8	10.1	8.6	2.7	7.7	3.7	8.5	2.3	2.0	2.8
	805	do	305	♀	11+18	82	4.0	5.6	9.2	10.0	2.7	7.8	4.0	8.2	2.1	1.9	2.7
Under 200 millimeters.	195	do	158	Im. ♂	10+16	83	3.9	5.3	9.2	8.2	2.9	7.9	4.3	9.8	2.2	1.9	2.6
	376	do	198	Im. ♂	12+18	87	3.8	5.5	10.1	8.5	2.8	8.1	4.2	9.0	2.1	1.9	2.7
	478	do	165	Im. ♂	11+18	80	3.8	5.5	9.5	9.0	2.9	7.8	4.6	9.4	2.0	1.9	2.7
	458	do	182	Im. ♀	11+18	81	3.9	5.4	9.5	8.6	2.8	7.9	4.4	9.1	2.0	1.9	2.7
	551	do	187	Im. ♀	11+16	85	3.8	5.5	9.9	8.9	2.6	8.1	4.5	8.1	1.8	1.8	2.6
	553	do	190	Im. ♀	12+19	82	4.0	5.6	9.9	9.4	2.9	7.6	4.8	9.5	1.9	1.9	2.7
	550	do	182	Im. ♀	11+18	79	3.9	5.3	8.0	9.3	2.6	7.7	4.9	9.1	1.8	1.9	2.6
	579	do	170	♂	11+19	76	3.8	5.2	9.1	8.0	2.8	8.7	4.7	9.1	1.9	1.9	2.6
	666	do	199	Im. ♂	11+16	81	4.0	5.5	9.3	8.0	2.7	8.1	4.2	9.5	2.2	2.0	2.7
	673	do	184	♂	12+18	73	4.0	5.5	9.5	8.9	2.8	8.1	4.2	8.0	1.8	2.0	2.7

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	51	2.9	4.1	4.5	2.7	3.5	2.0	3.4	6.6	3.2	1.9	2.5	1.6	1.3	8	13	11	18	1.6	1.0	8
	79	3.1	4.4	4.6	2.6	3.5	2.0	3.4	6.7	3.2	1.8	2.5	1.8	1.4	10	13	11	17	1.6	.90	9
	86	3.2	4.5	4.7	2.7	3.6	2.0	3.7	7.0	3.3	1.9	2.6	1.7	1.5	10	12	11	18	1.7	1.0	9
	90	3.2	4.4	4.5	2.7	3.5	2.0	3.6	7.3	3.3	2.0	2.6	1.6	1.4	9	12	11	17	1.6	1.0	8
	140	3.1	4.4	4.6	2.6	3.4	1.9	3.4	6.5	3.3	1.9	2.4	1.8	1.4	9	12	11	19	1.5	.92	9
	150	3.1	4.5	4.5	2.6	3.5	2.0	3.4	6.0	3.1	1.8	2.4	1.6	1.4	10	12	11	18	1.5	.91	9
	201	3.1	4.3	4.5	2.5	3.3	2.0	3.7	5.7	3.2	1.8	2.3	1.6	1.4	10	12	11	17	1.5	.90	9
	773	3.2	4.4	4.6	2.6	3.4	2.0	3.5	6.8	3.3	1.9	2.5	1.8	1.4	10	11	12	17	1.6	1.0	9
	777	3.1	4.5	4.6	2.6	3.3	1.9	3.3	5.7	3.2	1.8	2.3	1.8	1.4	9	11	11	17	1.6	.89	9
	805	3.1	4.3	4.5	2.5	3.3	1.9	3.5	6.8	3.2	1.8	2.4	1.8	1.5	10	11	11	17	1.5	1.0	8
Under 200 millimeters.	195	2.9	4.0	4.0	2.6	3.4	1.9	3.6	6.0	2.9	1.9	2.5	1.5	1.3	10	12	11	17	1.6	.89	8
	376	3.0	4.3	4.2	2.7	3.6	2.1	3.9	7.3	2.9	1.8	2.5	1.7	1.4	10	13	11	18	1.7	.98	9
	478	2.9	4.1	4.1	2.5	3.4	1.9	3.8	6.8	2.9	1.8	2.4	1.5	1.3	10	11	11	17	1.7	1.0	9
	458	2.9	4.1	4.2	2.6	3.4	1.9	4.1	6.9	3.0	1.9	2.4	1.6	1.3	10	12	11	17	1.6	.92	9
	551	2.9	4.1	4.3	2.7	3.4	1.9	3.6	6.6	3.0	1.9	2.4	1.6	1.2	10	12	11	16	1.8	.93	8
	553	3.0	4.2	4.1	2.5	3.5	1.9	3.7	5.9	2.9	1.7	2.4	1.5	1.4	10	11	12	19	1.5	.93	8
	550	3.0	4.0	4.1	2.8	3.5	1.9	4.1	6.0	3.0	2.0	2.6	1.4	1.2	10	11	11	18	1.8	.94	9
	579	2.8	3.9	4.0	2.5	3.3	1.9	4.1	6.2	2.9	1.8	2.4	1.6	1.3	11	14	11	17	1.5	.89	8
	666	2.9	4.0	4.2	2.7	3.3	1.9	3.2	5.9	3.1	2.0	2.4	1.6	1.2	10	13	12	17	1.4	.80	9
	673	2.9	4.1	4.1	2.4	3.5	2.0	3.7	6.3	3.0	1.7	2.5	1.6	1.2	10	12	11	17	-----	1.0	9

TABLE 20.—*Records of the occurrence of Leucichthys alpenæ in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of alpenæ	Preserved specimens examined	
									+200 mm.	−200 mm.
Washington Harbor, Wis.	1	Aug. 18, 1920	4 miles west of Boyer Bluff.	2⅜	18–24			(1)	2	
	2	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅜	71–90	Clay, mud	900	(1)	2	
Sturgeon Bay, Wis	3	Aug. 23, 1920	12 miles E. by S. of channel mouth.	2⅜, 2¾	60–70	Mud	50	(1)		
Algoma, Wis	4	Aug. 24, 1920	10 miles E. by N	2½	35–50	Gravel, mud	310	(1)	1	
Sheboygan, Wis	5	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	(2)	2	
Port Washington, Wis.	6	Sept. 25, 1920	18 miles E. ½ S	2½	65–48	do	285	(1)	1	
	7	do	5 miles E. ½ S	1½	30			(1)		1
D. H. Smith [3]	8	1892–1894	Sheboygan Reef, about halfway between Port Washington and Muskegon.							
Milwaukee, Wis	9	Sept. 23, 1920	27 miles ESE	2½	60	Red clay	250	(1)	1	
	10	Nov. 15, 1920	20 miles ESE	2½	28–35		700	(1)	4	
Michigan City, Ind	11	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30–40	Clay		10	9	
	12	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Clay, mud	535	20	3	
	13	Nov. 8, 1920	18 miles NNW	2½	30–38	Clay	1,000	33	4	
	14	Nov. 19, 1920	17 miles NNW	2½	28–32	do	700	30	5	
	15	do	17½ miles NW. by N. ¾ N.	2½	32	do		15	2	
	16	do	10 miles NNW	2½	18			(1)		
	17	Mar. 2, 1921	21 miles NNW	2½	30	Clay	1,000	(1)		
	18	Mar. 4, 1921	15 miles NW. by N. ½ N.	2½	28			(1)		
Grand Haven, Mich	19	Mar. 20, 1919	12 miles west	2¾	50–55	Clay		(2)	7	
Frankfort, Mich	20	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	22	5	
Platte Bay, Mich. (field station).	21	July 21, 1923	1½ miles south of Otter Creek.	1½	8–12	Sand		(4)		1
	22	July 23, 1923	do	1½	15–25	do		(4)		1
South Manitou Island, Mich.	23	July 30, 1923	Off the lighthouse	(5)	5				3	
Northport, Mich	24	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40–60	Mud	200	98	8	
	25	June 23, 1920	Off Northport Point	1½	28–40	do		(6)	1	9
	26	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40–60		400	45	156	
Hans Anderson, Peter Anderson, Walter Wilson	27	Nov., 1923	Grand Traverse Bay	2¾	10–25	Mud, stone				
Traverse City, Mich	28	July 18, 1923	West Bay	1½	30–40	Clay		(1)		
	29	July 25, 1923	Off Lees Point	1½	6–16			(4)		1
Will Hopkins	30	Nov., 1923	Grand Traverse Bay	2¾	10–25	Mud, clay				
Beaver Island, Mich., James Martin.	31	do	Sandy Bay	2¾	10–25	Mud, stone				
Charlevoix, Mich	32	June 29, 1920	5 miles N. by E	2¾	40–55	Clay, mud		98	8	
	33	June 15, 1923	Off Ile Aux Galets	2¾	25–47				2	
	34	Aug. 10, 1923	8 miles NNW. of Big Rock Point.	2¾	45–50	Clay	477	90	1	
	35	Aug. 11, 1923	3 miles NW. ½ W	2¾	35–60	Red clay	375	69	3	
	36	Aug. 21, 1923		2¾			100	91	52	
John Nordrum, Chas. Hendrickson, sr.	37	Nov., 1923	Grand and Little Traverse Bays.	2¾	10–25	Mud, stone				
Manistique, Mich	38	Aug. 11, 1920	13 miles SE. ½ E	4½	20	Sand, mud		(1)	1	
	39	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70		200	50	5	

[1] Rare.
[2] Lift not examined or percentage not ascertained.
[3] Where fishermen's names or other sources appear opposite the record number the data entered in the table were obtained from these sources.
[4] Only specimens taken in lift.
[5] Pound.
[6] Occasional.

TABLE 21.—*Numerical expressions of certain systematic characters for the type of Leucichthys alpenæ and for nine cotypes from Lake Michigan over 200 millimeters long and for nine under 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length, millimeters	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	[1]87352	Charlevoix, Mich	269	14+25	♀	75	4.4	5.9	9.1	9.9	2.7	8.1	4.2	7.6	1.8	2.2	2.9
	1587	Grand Haven, Mich	275	14+24	♀	80	4.3	6.0	9.6	10.1	2.8	8.0	3.9	7.2	1.8	2.1	2.9
	2864	Charlevoix, Mich	284	15+25	♀	81	4.2	5.7	9.4	9.4	2.7	9.1	3.9	7.2	1.8	2.1	2.8
	2879	do	285	16+28	♀	74	4.1	5.5	8.9	8.9	2.7	10.0	4.0	7.9	1.9	2.0	2.8
	2938	Manistique, Mich	275	14+25	♀	83	4.2	5.9	8.9	8.8	2.9	8.8	4.3	8.3	1.9	2.1	2.9
	2940	do	301	15+28	♀	76	4.4	6.1	9.4	10.0	2.7	8.8	4.1	7.5	1.8	2.2	3.0
	2941	do	317	13+25	♀	76	4.2	5.7	9.1	9.9	2.8	7.9	3.8	7.8	2.0	2.1	2.9
	2951	do	276	16+26	♂	80	4.2	5.8	8.4	10.6	2.6	7.4	3.5	7.8	2.2	2.1	2.8
	4378	Michigan City, Ind	245	12+22	♀	83	4.5	5.9	8.7	9.8	2.6	8.1	3.9	7.4	1.8	2.2	2.9
	4395	do	291	14+22	♀	75	4.4	5.7	10.3	11.4	2.9	7.9	4.2	8.0	1.9	2.1	2.8
Under 200 millimeters.	1779	Northport, Mich	178	16+27	Im. ♀	76	4.2	5.8	11.4	10.4	2.9	8.0	5.1	9.3	1.8	2.0	2.7
	1785	do	165	14+24	Im. ♀	84	4.1	5.3	10.3	9.8	2.9	8.0	4.8	8.6	1.7	1.9	2.5
	1793	do	178	15+24	Im. ♀	84	4.3	5.9	9.4	9.4	2.7	8.4	4.5	9.3	2.0	2.0	2.8
	1813	do	174	15+26	Im. ♀	79	4.0	5.6	10.4	10.4	3.1	7.5	4.5	10.2	2.2	1.9	2.6
	2707	do	182	14+24	Im. ♂	81	4.1	5.5	9.6	10.7	2.8	7.2	4.9	9.5	1.9	2.0	2.6
	2717	do	170	14+24	Im. ♀	80	4.0	5.6	10.3	9.8	2.9	8.9	5.1	9.7	1.8	1.9	2.7
	2749	do	173	16+28	Im. ♂	86	4.2	5.5	10.8	9.7	2.9	7.2	5.0	10.1	2.0	1.9	2.6
	2769	do	160	15+24	Im. ♂	79	4.1	5.5	10.6	10.5	3.0	8.3	4.8	9.4	1.9	2.0	2.7
	2780	do	193	15+27	Im. ♂	83	4.2	5.8	9.6	10.2	2.8	8.3	4.8	9.6	2.0	2.1	2.8

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	[1]87352	3.5	4.7	4.6	2.7	3.7	1.9	3.3	5.9	3.4	2.0	2.6	2.2	1.8	10	11	11	16	1.3	0.91	8
	1587	3.3	4.6	4.5	2.5	3.7	1.9	3.1	6.8	3.2	1.8	2.6	2.2	1.6	11	11	10	15	1.5	.98	9
	2864	3.2	4.3	4.5	2.5	3.5	2.0	3.9	6.5	3.3	1.8	2.6	2.1	1.5	10	12	11	16	1.3	.88	9
	2879	3.2	4.4	4.5	2.6	3.6	2.0	4.0	5.8	3.3	1.9	2.7	2.2	1.6	11	12	12	17	1.4	.88	9
	2938	3.3	4.6	4.5	2.6	3.6	1.9	3.5	5.5	3.2	1.9	2.6	1.9	1.6	11	13	11	17	1.4	1.0	9
	2940	3.4	4.7	4.5	2.6	3.1	2.0	3.8	5.6	3.2	1.8	2.2	2.1	1.8	10	11	11	16	1.4	.96	8
	2941	3.3	4.4	4.9	2.6	3.0	2.0	3.5	5.7	3.6	1.9	2.2	2.0	1.8	11	12	11	17	1.3	.94	10
	2951	3.2	4.3	4.6	2.5	3.5	1.8	3.7	6.3	3.3	1.8	2.6	2.0	1.5	10	11	11	16	1.3	1.0	9
	4378	3.4	4.5	4.2	2.5	3.8	1.8	3.4	6.4	3.2	1.9	2.9	2.0	1.5	11	11	11	16	1.4	1.1	9
	4395	3.4	4.4	4.7	2.5	3.3	1.9	3.1	7.3	3.6	2.0	2.5	2.2	1.7	10	9	11	15	1.4	1.1	9
Under 200 millimeters.	1779	3.1	4.3	4.2	2.6	3.5	1.9	3.7	6.0	3.0	1.9	2.5	2.1	1.6	9	11	11	15	1.6	.94	9
	1785	3.2	4.1	4.2	2.6	3.5	2.0	3.7	6.4	3.2	2.0	2.7	2.1	1.7	10	11	11	16	1.5	------	9
	1793	3.3	4.5	4.1	2.6	3.4	1.9	3.4	6.0	3.0	1.9	2.5	2.1	1.5	11	12	11	16	1.5	.92	9
	1813	3.0	4.2	4.3	2.7	3.8	2.0	3.8	6.2	3.1	2.0	2.8	2.2	1.7	11	12	11	16	1.5	1.0	9
	2707	3.0	4.1	4.3	2.7	3.3	1.9	3.6	6.7	3.2	2.0	2.5	1.9	1.5	10	10	11	15	1.5	1.0	9
	2717	3.0	4.1	4.3	2.6	3.7	1.8	3.8	6.1	3.1	1.8	2.6	1.9	1.4	9	11	11	16	1.6	.98	9
	2749	3.1	4.1	4.0	2.5	3.6	1.9	3.6	6.6	3.0	1.9	2.7	1.9	1.6	10	12	11	17	1.6	.91	9
	2769	3.1	4.2	4.2	2.6	3.8	1.8	3.6	6.2	3.1	1.9	2.8	1.9	1.4	9	11	11	15	1.7	1.0	9
	2780	3.2	4.3	4.1	2.7	3.6	1.9	3.7	5.7	3.0	2.0	2.7	1.9	1.6	10	12	12	17	1.5	1.0	9

[1] Type, U. S. National Museum number.

TABLE 22.—*Records of the occurrence of Leucichthys alpenæ in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Lake Huron proper:										
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef.	2¾	35–50	Clay			6	6
	2	Sept. 29, 1917	2 miles northeast of Spectacle Reef.	2¾	35–50	do	1,850	(1)		3
	3	Oct. 15, 1919		1½	35			(2)		42
Rogers, Mich	4	July 24, 1917		2¾	60–70	Clay		(3)	9	
Emil Schmekel.	5	Sept. 17–30, 1917		4½	12–15	Rock		(2)		
	6	Oct. 14, 1917	12 miles E. by N. ½ N.	2¾	35–50	Clay	1,500	(1)	1	4
Alpena, Mich	7	Aug. 13, 1917	38 miles east of can buoy.	2¾	70–80	do	1,470		12	7
	8	Sept. 7, 1917	Center of lake, east of can buoy.	2¾	70–80	do	3,250	(1)		
	9	do	26 miles SE. by E. ¼ E. of can buoy.	4½	16–20			(5)		2
	10	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30			(1)		1
	11	Sept. 10, 1917	8 miles E. by N. of can buoy.	4½	20			(5)	1	
	12	do	Center of lake, northeast of can buoy.	2¾	60–70	Clay	1,300	(1)		
	13	Sept. 12, 1917	Center of lake, east of can buoy.	2¾	65–80	do	2,610	(1)		
	14	Sept. 14, 1917	24 miles SE. by E. ½ E. of can buoy.	4½	24			(5)	1	5
	15	do	Center of lake, northeast of can buoy.	2¾	65–80	Clay	1,200	(1)	1	5
	16	Sept. 17, 1917	do	2¾	60–70	do		(1)	1	
	17	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60	do	825	(3)	4	12
	18	Sept. 19, 1917	23 miles SE. by E. ½ E. of can buoy.	2¾	30	Rock		(1)	1	
	19	do	Center of lake, northeast of can buoy.	2¾	65–80	Clay		(3)		1
	20	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65	do		(3)		4
	21	Sept. 21, 1917	Center of lake, east of can buoy.	2¾	65–70	do		(1)	3	6
	22	do	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–75	do		(3)		1
	23	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy.	4½	17			(5)		1
	24	Sept. 24, 1917	Center of lake, east of can buoy.	2¾	65–80	Clay		(1)		
	25	Sept. 26, 1917	do	2¾	65–80	do		(1)		
	26	do	13 miles SE. by S. of can buoy.	2¾	17			(1)	1	
	27	Oct. 17, 1917	Center of lake, east of can buoy.	2¾	65–80	Clay		(1)	4	
	28	Oct. 20, 1917	do	2¾	65–80	do		(1)		
	29	Aug. 30, 1919	18 miles N. by E. ½ E. of Thunder Bay Island.	2¾	60–64	do		20		
	30	Sept. 3, 1919	28 miles E. ¼ S. of can buoy.	2¾	60–64	do		20		
	31	Sept. 16, 1919	40 miles ESE. of can buoy.	4½	20–30			(1)		1
	32	Sept. 18, 1919	14 miles N. by E. of Thunder Bay Island.	2¾	65	Clay		(3)		1
	33	Aug. 7, 1920	19 miles NE. ½ N. of Thunder Bay Island.	2¾	60–65		3,500	(1)		
	34	June 28, 1923	19 miles northeast of Thunder Bay Island.	2¾	60–70		2,100	(1)		
	35	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–70	Clay	1,600	7		13
	36	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60–70	do	2,000	3	5	
	37	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80–100	do	6,000	(1)		4
	38	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60	do	1,400	22	2	11
	39	July 10, 1923	3 miles E. ½ S. of North Point.	4½	14–20	Rock, mud.		(5)		8

[1] Rare.
[2] Occasional.
[3] Lift not examined or percentage not ascertained.
[4] See note, Table 20.
[5] Only specimens taken in lift.

TABLE 22.—*Records of the occurrence of Leucichthys alpenæ in Lake Huron*—Continued

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined	
									+200 mm.	−200 mm.
Lake Huron proper—Continued.										
Tug records	40	April–November, 1923.		4½	20–30			(1)		
Bay City, Mich.	41	Oct. 29, 1921	Saginaw Bay at Tobico.	(6)	3			(1)	1	
	42	Nov. 25, 1925	Saginaw Bay at Nayanquing.	(6)	3			(1)		3
Harbor Beach, Mich.	43	Oct. 27, 1917	35 miles NE. by N. ¾ N. of city.	2¾	50	Clay	1,183	48	6	7
	44	Mar. 15, 1919		1½	31	do		21		46
Duck Islands, Ontario, A. Purvis.	45	May–August, 1919.	Off the islands	4½	20–30	Rock and gravel.				
North Channel:										
John Merrylees	46	August, 1919	Off Gore Bay Light	4½	20–25					
D. Beneteau	47	January–February, 1919.	North Channel	4½	20–25					
Georgian Bay:										
Lions Head, Ontario.	48	July 30, 1919	21 miles east of Surprise Shoal.	3	60	Mud	400	48	16	12
	49	Oct. 6, 1919	Off White Bluff	3	70	do	425	(1)	4	2
Wiarton, Ontario	50	Nov. 6, 1927	6½ miles northeast of Griffith Island.	3	45–60	do		(3)	13	1
	51	July 28, 1919	Off Cape Croker	3	52	do	500	50	21	4
	52	July 30, 1919		3						5
Stanley Boyd	53	Nov. 19, 1919	Colpoys Bay	3						
	54	Nov. 28, 1919	do	3	10–25	Mud, rock	755	100	10	2
	55	Dec. 3, 1919	do	1½–3	10–25	do	380	100	6	2
	56	June 10, 1922	Off Cape Croker	3					49	
	57	June 26, 1923	do	3						
Owen Sound to Meaford, D. McInnis.	58	November and early December, 1923.	In sound and along shore.		10–25					

[1] Rare. [3] Lift not examined or percentage not ascertained. [6] Pound net.

TABLE 23.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys alpenæ from Lake Huron, 10 of them more than 200 millimeters long and 10 less than 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length, millimeters	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	DW	SD/H	SD/O
Over 200 millimeters.	844	Cheboygan, Mich.	315	♀	14+25	82	4.2	6.1	10.0	10.7	2.8	7.8	4.0	8.5	2.1	2.2	3.1
	62	do	260	♀	14+24	79	4.1	5.7	8.8	9.1	2.8	8.2	4.1	8.9	2.1	2.0	2.8
	141	Alpena, Mich.	305	♀	13+24	78	4.1	6.1	10.0	10.1	2.8	8.2	4.0	8.0	2.0	2.2	3.0
	143	do	296	♀	14+24	74	3.9	5.5	10.0	9.8	2.8	7.8	4.3	9.2	2.1	2.0	2.8
	142	do	337	♂	14+25	81	4.1	5.7	8.3	9.3	2.8	8.4	4.0	8.4	2.1	2.0	2.9
	147	do	310	♀	13+23	75	4.1	5.9	10.0	10.2	2.8	8.8	3.7	7.4	2.0	2.1	3.0
	144	do	274	♀	13+24	82	4.2	6.1	9.2	10.4	2.7	8.6	4.2	7.7	1.8	2.0	2.9
	137	do	299	♂	15+23	80	4.2	6.0	10.0	9.2	2.7	8.2	3.8	7.6	1.9	2.0	2.9
	146	do	289	♀	15+25	80	4.1	5.6	9.0	10.5	2.7	8.4	3.7	7.8	2.0	2.0	2.8
	136	do	342	♀	13+24	78	4.2	6.0	10.3	11.0	2.9	8.1	3.9	7.6	1.9	2.1	3.0
Under 200 millimeters.	42B	Harbor Beach, Mich.	169	Im. ♀	13+23	77	4.1	5.6	9.3	8.8	2.8	8.0	4.3	8.2	1.9	2.0	2.7
	49B	do	178	♀	13+22	79	4.2	5.7	10.0	9.6	2.8	8.0	4.5	7.9	1.7	2.0	2.7
	57B	do	173	♀	13+23	84	4.1	5.7	10.2	10.0	2.8	7.8	4.4	8.4	1.8	2.0	2.8
	59B	do	189	Im. ♀	13+23	83	4.1	5.8	10.0	10.9	3.0	7.8	4.2	8.2	1.9	2.0	2.8
	60B	do	161	Im. ♂	12+21	79	4.1	5.3	8.8	10.0	2.8	8.0	4.1	7.6	1.8	2.0	2.6
	61B	do	157	Im. ♂	12+21	77	3.9	5.2	11.2	9.2	2.9	7.9	4.1	8.3	2.0	1.9	2.6
	72B	do	161	Im. ♂	11+20	72	4.0	5.4	9.0	9.2	2.8	8.0	4.6	8.2	1.7	1.9	2.6
	73B	do	165	Im. ♂	13+23	76	3.9	5.3	9.7	9.1	2.9	7.1	4.3	9.0	2.0	1.9	2.6
	74B	do	156	Im. ♂	12+21	76	4.2	5.6	10.0	9.6	2.9	8.2	4.3	8.8	2.0	2.0	2.8
	75B	do	164	Im. ♀	12+20	76	3.9	5.2	9.1	9.7	2.9	8.5	4.2	7.6	1.8	1.9	2.5

TABLE 23.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys alpenæ from Lake Huron, 10 of them more than 200 millimeters long and 10 less than 200 millimeters long, selected according to size*—Continued

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	844	3.2	4.7	4.7	2.6	3.8	1.9	4.2	5.7	3.2	1.8	2.6	2.1	1.7	11	11	11	15	1.3	0.91	9
	62	3.2	4.5	4.8	2.6	3.4	2.0	3.6	6.2	3.4	1.8	2.5	1.9	1.7	11	12	11	16	1.3	.87	8
	141	3.4	4.8	4.6	2.7	3.6	1.9	3.7	5.6	3.3	1.9	2.6	2.1	1.8	10	11	11	16	1.4	.98	8
	143	3.1	4.3	4.5	2.4	3.5	1.9	4.7	7.1	3.2	1.7	2.5	1.8	1.6	10	12	11	16	1.6	.98	9
	142	3.2	4.5	4.7	2.6	3.4	1.8	3.2	5.7	3.4	1.8	2.4	1.9	1.6	11	11	11	16	1.2	.94	9
	147	3.3	4.7	4.8	2.5	3.5	1.8	3.5	7.2	3.4	1.7	2.4	2.2	1.6	10	10	11	16	1.4	1.0	10
	144	3.2	4.7	4.6	2.5	3.4	1.9	3.7	5.8	3.2	1.7	2.4	2.0	1.7	10	12	11	16	1.3	.99	9
	137	3.3	4.7	4.6	2.5	3.5	2.0	3.5	6.6	3.3	1.7	2.5	2.0	1.5	10	11	11	16	1.6	.98	8
	146	3.2	4.4	4.8	2.6	3.4	2.1	3.7	6.3	3.5	1.9	2.4	2.0	1.6	10	11	11	16	1.2	.92	9
	136	3.3	4.7	4.8	2.5	3.4	1.9	3.5	6.2	3.3	1.6	2.4	2.2	1.8	10	10	11	15	1.3	1.0	10
Under 200 millimeters.	42B	3.1	4.1	4.0	2.5	3.6	1.9	3.4	6.6	2.9	1.8	2.6	2.0	1.4	11	13	11	16	1.5	.90	9
	49B	3.2	4.3	3.8	2.5	3.7	1.8	3.8	6.3	2.9	1.8	2.8	2.2	1.6	10	11	11	16	1.5	.87	9
	57B	3.1	4.3	3.8	2.4	3.7	1.8	3.4	5.9	2.7	1.7	2.6	2.1	1.3	10	11	11	16	1.6	1.0	9
	59B	3.1	4.4	3.8	2.3	3.6	1.8	3.7	6.3	2.7	1.6	2.6	2.1	1.4	9	9	11	15	1.5	1.0	9
	60B	3.1	4.1	3.9	2.4	3.5	1.7	3.8	6.7	3.0	1.9	2.6	2.0	1.4	11	12	10	16	1.4	1.0	8
	61B	2.9	4.0	3.8	2.5	3.4	1.8	3.8	7.3	2.8	1.8	2.6	1.8	1.4	10	12	12	16	1.8	1.0	9
	72B	3.0	4.0	3.9	2.4	3.6	1.9	3.5	8.0	2.9	1.8	2.7	2.0	1.5	11	12	10	16	1.4	.90	10
	73B	3.0	4.0	3.9	2.4	3.9	1.8	3.7	6.9	2.9	1.8	2.9	2.0	1.4	10	11	11	17	1.6	1.0	9
	74B	3.1	4.2	3.7	2.5	4.0	1.8	3.1	6.1	2.7	1.8	2.9	2.0	1.4	11	12	11	15	1.5	.88	9
	75B	3.1	4.1	4.0	2.3	3.6	1.8	3.5	6.9	3.0	1.7	2.9	2.0	1.5	10	11	11	16	1.5	1.0	8

TABLE 24.—*Records of the occurrence of Leucichthys zenithicus in Lake Superior*

[For each record is given, if known, the date and locality, the kind and quantity of gear used to make it, the depth of the water and character of the bottom where made, the number of fish gilled in the netting, the percentage of this species among them, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms
Sault Ste. Marie, Mich.	1	June 14, 1922	10 miles NW. by W. ¼ W. of Point Iroquois Light in Whitefish Bay.	2½, 2¾	38
Grand Marais, Mich.	2	Oct. 3, 1917		4½	+65
Marquette, Mich.	3	Aug. 5, 1921	31 miles N. ¾ E.	4½	100
	4	Aug. 8, 1921	6 miles NE. ¾ N.	1½, 2½, 2¾	42–65
	5	Aug. 11, 1921	18 miles NE. by N.	2½, 2¾	100–80
	6	Dec. 5, 1922	Off Granite Island	4½	
	7	1923			
	8	November, 1925			
W. J. Parker [1]	9	Nov. 25-Dec. 1	10 miles N. by W. ¼ W.	2¾	20–40
Ontonagon, Mich.	10	Aug. 16, 1921	54 miles W. by N.	4½	25–80
	11	Aug. 24, 1921	21 miles west	2½, 2¾	15–45
	12	Aug. 25, 1921	6 miles NNW.	2½, 2¾	20–38
Apostle Islands, Wis.	13	July 11, 1922	Between Cat and South Twin Island	2½, 2¾	15–20
	14	July 14, 1922	25 miles north of South Twin Island	4½	50–90
	15	July 15, 1922	14–18 miles NW. by N. of South Twin Island	4½	40–90
	16	do	20 miles northwest of Rocky Island	4½	35–65
Duluth, Minn.	17	July 17, 1922	20 miles NE. by E.	2⅝	30–40
Grand Marais, Minn.	18	Sept. 14, 1921	Off Terrace Point	2½, 2¾	30–65
	19	July 17, 1922	do	4½	30–65
Port Arthur, Ontario	20	Sept. 15, 1923	North of Silver Island	2½	14
	21	do	Thunder Bay, off Thunder Cape	2½	31
	22	Sept. 17, 1923	Thunder Bay, north of Welcome Islands	2½	11
	23	do	Thunder Bay, south of Welcome Islands	2½	23
	24	Sept. 19, 1923	Thunder Bay, off Sawyer Bay	2½	49
Rossport, Ontario	25	Oct. 4, 1921	Off Bread Rock	2½, 2¾	80–90
	26	Sept. 25, 1923	Simpson Channel	2½	74
	27	Sept. 29, 1923	Off Salter Island	2½	42
Port Coldwell, Ontario	28	Oct. 22, 1923		4½	
Michipicoten Island, Ontario	29	June 19, 1922	6 miles northeast of East End Light	4½	15–35
	30	June 22, 1922	3 miles SE. ½ E. of Quebec Harbor Light	2½, 2¾	80
Coppermine Point, Ontario	31	June 24, 1922	Agawa Bay	4½	40–50
	32	June 26, 1922	Off Alona Bay	2½, 2¾, 4½	60

TABLE 24.—*Records of the occurrence of Leucichthys zenithicus in Lake Superior*—Continued

Port from which nets were set	Record No.	Bottom	Length of net, in feet	Nights set	Number of fish gilled	Percentage of zenithicus	Preserved specimens examined	
							+200 mm.	−200 mm.
Sault Ste. Marie, Mich	1		1,800	2	200	99	79	9
Grand Marais, Mich	2						27	25
Marquette, Mich	3	Reddish-brown clay					18	52
	4	Red clay	2,500	5	250	96	57	36
	5		2,500	7	200	88	19	2
	6						16	50
	7						1	
	8						2	
W. J. Parker [1]	9	Clay				(2)		
Ontonagon, Mich	10						11	
	11	Red clay	2,500	7	700	99	39	3
	12	Sand and clay	2,500	7	500	97	53	6
Apostle Islands, Wis	13	Sand	2,200	1	300	99	185	
	14	Red and yellow clay					2	2
	15	Clay					3	8
	16	do					4	7
Duluth, Minn	17	Sand					48	3
Grand Marais, Minn	18	Clay	3,500	7	2,000	98	39	1
	19	do					17	4
Port Arthur, Ontario	20	Mud	500	1	32	3	1	
	21	Brownish-gray clay	500	2	70	50	32	
	22	Clay	500	2	16	(3)	1	
	23	Brownish-gray clay	1,000	2	121	6	8	
	24	do	1,000	2	50	62	26	
Rossport, Ontario	25	Grayish-brown clay	1,000	4	210	89	42	
	26	Clay	1,000	1	4	100	4	
	27	do	1,000	4	25	92	22	
Port Coldwell, Ontario	28						1	
Michipicoten Island, Ontario	29						24	7
	30	Blue clay	2,500	3	75	79	30	1
Coppermine Point, Ontario	31	Mud						2
	32		1,800	5	200	87	68	8
Marquette, Mich. [4]							7	
Devil Island [4]							1	
Knife River, Minn. [5]							3	
Duluth, Minn. [5]							1	

[1] See note, Table 20.
[2] Abundant.
[3] Rare.
[4] Field Museum collection, borrowed specimens.
[5] U. S. National Museum collection, borrowed specimens.

TABLE 25.—*Numerical expressions of certain systematic characters for the type of Leucichthys zenithicus and for 19 other specimens from Lake Superior, 9 of them over 200 millimeters long and 10 under 200 millimeters, selected according to size*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	[1]62517	Isle Royale, Mich.	278	17+28	♂	74	3.7	5.1	10.0	8.7	2.8	9.0	4.7	9.0	1.9	1.8	2.5
	53882	Rossport, Ontario.	265	16+25	♀	80	3.9	5.3	9.4	9.3	2.8	7.3	4.0	7.1	1.7	2.0	2.7
	53888	do	254	15+25	♀	80	4.0	5.3	9.0	9.4	2.8	8.1	4.2	7.8	1.8	2.0	2.7
	53894	do	266	16+27	♀	76	4.0	5.4	9.4	9.8	2.8	7.6	4.1	8.0	1.9	2.0	2.7
	53897	do	286	15+27	♀	79	4.1	5.5	8.7	9.2	2.8	8.1	4.4	8.2	1.8	2.0	2.7
	53901	do	277	15+25	♂	74	3.8	4.9	8.9	9.2	2.8	8.3	4.3	9.3	2.1	1.9	2.4
	57033	Michipicoten Island, Ontario.	263	16+28	♂	82	4.0	5.4	9.7	9.0	2.7	8.2	4.1	8.2	1.9	2.0	2.7
	57067	Alona Bay	233	15+24	♀	83	4.0	5.2	9.7	9.7	2.8	6.7	4.2	8.6	2.0	2.0	2.6
	58095	Apostle Islands.	263	15+25	♀	75	4.0	5.2	10.0	9.7	2.7	7.7	4.6	9.3	2.0	2.0	2.6
	58104	do	257	14+25	♀	80	4.0	5.1	10.0	9.6	2.7	7.4	4.5	8.0	1.7	1.9	2.5
Under 200 millimeters.	53380	Marquette, Mich.	155	14+23	♂	86	3.7	4.8	9.8	8.5	2.9	7.4	4.4	9.3	2.1	2.0	2.5
	53651	Ontonagon, Mich.	170	15+23	Im. ♀	81	4.0	5.6	10.4	10.4	2.8	7.4	5.3	8.9	1.6	1.9	2.7
	53655	do	185	13+24	Im. ♂	75	3.8	5.1	9.7	9.7	2.8	7.5	4.4	9.2	2.0	1.9	2.5
	53661	do	195	16+26	♂	79	4.0	5.4	8.5	9.3	2.7	8.4	4.4	8.1	1.8	2.0	2.6
	53805	Grand Marais, Minn.	168	16+24	♀	79	4.0	5.2	9.8	9.7	2.9	7.3	4.0	8.4	2.1	2.0	2.7
	57059	Alona Bay	188	13+23	♂	80	4.0	5.1	9.0	8.2	2.8	7.8	4.5	8.7	1.9	1.9	2.5
	57820	Michipicoten Island, Ontario.	191	14+24	♀	80	4.0	5.4	9.0	10.1	2.7	7.3	4.5	8.6	1.9	2.0	2.6
	57832	do	171	14+23	♂	72	4.0	4.6	10.5	8.6	3.1	7.7	4.7	9.5	2.0	1.9	2.4
	57944	Whitefish Bay.	189	15+24	♀	69	3.9	5.0	9.8	9.4	3.0	8.5	5.2	9.9	1.8	1.9	2.5
	58471	Grand Marais, Minn.	183	14+23	♀	76	3.8	5.0	9.1	8.7	2.9	8.3	4.4	8.1	1.8	1.8	2.4

[1] Type, U. S. National Museum number.

TABLE 25.—*Numerical expressions of certain systematic characters for the type of Leucichthys zenithicus and for 19 other specimens from Lake Superior, 9 of them over 200 millimeters long and 10 under 200 millimeters, selected according to size*—Continued

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	[1] 62517	2.9	4.0	4.6	2.5	3.5	2.0	4.2	6.2	3.3	1.8	2.5	1.6	1.3	10	12	12	16	1.7	1.0	10
	53882	3.0	4.1	4.4	2.4	3.4	2.0	3.6	5.9	3.3	1.8	2.6	2.0	1.4	10	12	11	16	1.5	.94	9
	53888	3.1	4.2	4.4	2.5	3.3	1.9	3.4	5.7	3.3	1.8	2.5	2.1	1.5	11	12	11	16	1.4	.95	9
	53894	3.0	4.2	4.4	2.4	3.7	2.0	3.4	6.6	3.2	1.8	2.7	1.8	1.6	10	10	11	15	1.4	.96	9
	53897	3.2	4.3	4.6	2.3	3.4	1.9	3.5	4.8	3.4	1.7	2.5	1.8	1.5	11	12	11	18	1.4	1.0	9
	53901	3.0	3.8	4.8	2.4	3.6	1.9	4.4	5.7	3.8	1.9	2.8	1.7	1.4	10	12	11	16	1.4	.94	9
	57033	3.0	4.1	4.7	2.5	3.5	2.0	3.6	5.9	3.4	1.8	2.5	1.7	1.5	10	11	11	17	1.5	.93	9
	57067	3.0	3.9	4.0	2.5	3.5	1.9	3.4	6.4	3.0	1.9	2.7	1.6	1.3	11	12	11	16	1.6	1.0	9
	58095	3.0	3.9	4.3	2.4	3.3	1.9	3.1	6.5	3.3	1.9	2.5	1.7	1.3	10	13	11	16	1.5	1.0	9
	58104	3.0	3.9	4.2	2.3	3.5	1.9	3.1	5.9	3.2	1.8	2.7	1.6	1.4	10	12	11	16	1.6	.98	9
Under 200 millimeters.	53380	2.9	3.7	3.7	2.6	3.6	2.1	4.0	7.0	2.9	2.0	2.8	2.0	1.2	11	13	11	16	1.6	.93	8
	53651	3.0	4.3	4.2	2.6	3.7	2.1	3.4	7.0	3.0	1.8	2.6	1.7	1.5	10	11	11	17	1.6	1.0	9
	53655	2.9	3.9	4.0	2.5	3.6	2.0	4.7	6.0	3.0	1.8	2.7	1.6	1.4	10	11	11	16	1.5	1.0	9
	53661	3.0	4.1	4.0	2.5	3.7	2.0	3.9	8.7	3.0	1.8	2.8	2.1	1.4	11	11	11	16	1.4	.96	9
	53805	3.0	4.0	3.8	2.5	3.5	1.9	3.0	7.0	2.9	1.9	2.6	1.5	1.3	10	10	11	16	1.7	1.0	9
	57059	3.0	4.0	4.2	2.4	3.5	2.0	3.4	7.5	3.2	1.8	2.7	1.9	1.3	10	12	11	16	1.5	.92	8
	57820	3.1	4.2	3.9	2.6	3.6	1.9	3.5	7.5	2.9	1.9	2.6	1.7	1.4	11	11	11	16	1.6	1.1	8
	57832	2.7	3.5	3.9	2.6	3.4	2.1	4.2	8.1	3.1	2.0	2.6	1.7	1.1	10	12	11	17	1.5	.94	8
	57944	2.8	3.7	4.1	2.6	3.4	2.0	4.1	8.0	3.1	2.0	2.6	1.5	1.1	10	12	11	17	1.7	1.1	9
	58471	3.0	3.9	3.8	2.4	3.4	1.8	3.6	7.8	2.9	1.8	2.6	1.8	1.4	11	12	11	15	1.6	.92	9

[1] Type, U. S. National Museum number.

TABLE 26.—*Records of the occurrence of Leucichthys zenithicus in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined	
					+200 mm.	−200 mm.
1	July 26, 1922	Off Macdiarmid	2½, 2¾	30	101	7
2	Sept. 10, 1923	do			2	1
3	July 21, 1924	do			3	
4	July 29, 1924	do		15	1	
5	July 25, 1924	Off Blackwater River		54	1	
6	Sept. 6, 1923	Off Selwyn Island			1	
7	Sept. 5, 1923	Off McKellar Island				1
8	Sept. 3, 1923	Humboldt Bay		6–35	1	1
9	Aug. 15, 1922	Off Murchison Island		25	5	
10	Aug. 23, 1923	Ombabika Bay		10	5	
11	July 19, 1924	do		10	5	
12	Aug. 17, 1922	Off Whitesand River		25	3	0
13	Aug. 1, 1922	Grand Bay	4½	15–20	1	
14	Aug. 25, 1921	Off source of Nipigon River		12	2	
15	June 15, 1922	do		15	1	
16	July 25, 1922	do	2½, 2¾	10–15	19	
17	Aug. 28, 1923	Off Virgin Island		10–15		5
18	Aug. 15, 1922	Unknown		25	3	
19	Oct. 26, 1922	do	4½		5	
20	June 14, 1924	do	4½		1	

[1] All but records 1, 13, 16, and 19 are from University of Toronto collections.

TABLE 27.—*Numerical expression of certain systematic characters for 20 specimens of Leucichthys zenithicus from Lake Nipigon, half of them over 200 millimeters long and half under 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	57454	Macdiarmid, Ontario.	247	♀	13+24	72	3.8	5.1	10.2	9.5	3.0	8.4	4.2	8.5	2.0	1.9	2.5
	57482	do	234	♀	12+23	70	3.8	4.8	8.9	8.6	2.9	8.5	3.9	8.6	2.2	1.9	2.5
	57484	do	252	♀	14+25	72	4.2	5.3	9.4	9.1	3.2	7.6	4.5	9.8	2.1	2.0	2.6
	57519	do	256	♀	14+25	71	3.9	5.2	9.5	9.0	3.0	9.8	4.4	8.2	1.8	2.0	2.6
	57531	do	274	♀	14+24	72	4.0	5.5	8.5	7.8	3.0	9.3	4.2	9.4	2.2	2.0	2.8
	57548	do	246	♀	13+24	76	3.9	5.2	9.1	10.4	3.1	8.2	4.3	9.1	2.0	1.9	2.5
	57575	do	259	♀	13+22	76	4.0	5.3	8.9	8.6	3.0	8.9	4.5	9.5	2.1	2.0	2.7
	57611	do	252	♀	13+24	77	4.0	5.3	8.3	9.6	2.9	8.3	4.5	9.3	2.0	2.0	2.6
	57617	do	265	♀	14+22	72	4.0	5.3	9.1	8.3	2.9	8.5	4.2	8.5	2.0	2.0	2.7
	57622	do	257	♀	14+26	74	4.0	5.1	9.1	10.2	2.7	9.1	4.0	8.8	2.1	2.1	2.6
Under 200 millimeters.	57510	do	186	Im. ♀	13+26	72	3.6	4.6	8.5	9.7	3.2	8.0	4.7	10.3	2.1	1.8	2.3
	57625	do	190	♂	14+25	70	3.8	5.0	8.2	9.4	2.9	8.4	4.4	10.5	2.3	1.8	2.4
	57633	do	196	♂	13+25	70	3.8	5.1	8.5	9.3	2.9	7.8	4.3	10.3	2.3	1.9	2.5
	57650	do	184	Im. ♀	15+26	77	3.9	5.2	9.6	10.2	2.9	7.0	5.1	10.2	2.0	2.0	2.7
	57673	do	192	Im. ♀	15+25	78	3.8	5.1	8.8	9.3	3.0	7.6	4.8	9.1	1.9	2.0	2.7
	57695	do	157	Im. ♀	13+24	76	3.8	5.0	8.3	8.3	2.8	8.3	5.1	9.3	1.8	1.9	2.5
	N840	Virgin Islands, Ontario.	199	♂	14+23	69	3.9	5.3	9.8	9.7	3.0	8.1	4.7	11.0	2.3	2.0	2.7
	N459	(?)	172	♂	13+22	73	3.8	4.8	8.6	9.0	2.9	9.0	4.0	10.1	2.4	2.0	2.5
	N460	(?)	161	Im. ♂	13+23	78	3.8	5.1	9.9	9.0	2.8	8.4	4.3	9.4	2.1	2.0	2.7
	[1] N461	(?)	155	Im. ♀	14+23	74	3.6	4.7	8.7	9.6	2.9	9.1	5.0	11.0	2.2	1.8	2.4

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	57454	3.0	4.0	4.5	2.5	3.2	1.9	3.5	7.1	3.4	1.8	2.4	1.8	1.4	10	11	10	16	1.7	1.0	9
	57482	2.9	3.7	4.1	2.4	3.2	1.9	3.4	5.8	3.2	1.9	2.5	1.6	1.5	10	12	11	16	1.6	.97	9
	57484	3.3	4.2	4.0	2.4	3.3	1.9	3.0	6.0	3.1	1.9	2.6	2.0	1.7	11	11	11	15	1.5	.92	10
	57519	3.1	4.1	4.4	2.3	3.2	1.9	3.6	5.9	3.3	1.7	2.4	1.8	1.6	10	12	11	16	1.6	1.0	9
	57531	3.1	4.4	4.5	2.4	3.4	1.9	4.0	6.6	3.2	1.7	2.4	1.9	1.6	10	12	10	16	1.3	.82	9
	57548	3.0	4.1	4.4	2.3	3.3	1.9	3.1	4.8	3.2	1.7	2.4	1.7	1.4	11	10	12	17	1.6	1.1	10
	57575	3.2	4.2	4.2	2.4	3.3	1.9	3.3	5.7	3.2	1.8	2.4	1.9	1.5	10	12	12	17	1.5	.93	9
	57611	3.1	4.1	4.1	2.3	3.4	1.9	3.4	5.5	3.1	1.7	2.6	1.9	1.6	11	11	12	17	1.3	1.0	9
	57617	3.1	4.1	4.2	2.4	3.2	1.8	3.5	7.2	3.1	1.8	2.4	2.0	1.6	10	11	12	16	1.5	.94	9
	57622	3.0	3.8	4.2	2.6	3.3	1.8	4.5	5.8	3.3	2.0	2.6	1.8	1.4	9	10	11	16	1.6	1.1	9
Under 200 millimeters.	57510	2.7	3.5	4.1	2.5	3.3	1.9	3.5	7.5	3.2	1.9	2.6	1.6	1.2	10	11	11	17	1.6	1.1	9
	57625	2.9	3.8	4.1	2.5	3.5	1.9	3.5	6.2	3.1	1.9	2.6	1.7	1.4	11	12	11	17	1.5	1.0	9
	57633	2.9	3.9	4.0	2.3	3.4	1.9	3.6	5.7	3.0	1.7	2.5	1.7	1.4	10	11	12	17	1.6	1.1	9
	57650	3.0	4.0	3.8	2.5	3.5	1.9	2.9	5.8	2.9	1.9	2.6	1.7	1.3	10	11	11	17	1.6	1.0	9
	57673	3.0	4.1	4.2	2.6	3.5	2.0	3.6	6.4	3.1	1.9	2.6	1.7	1.4	11	11	12	17	1.6	1.0	9
	57695	2.8	3.8	3.6	2.4	3.6	1.9	4.1	5.4	2.7	1.8	2.7	1.7	1.3	10	12	12	16	1.6	.96	9
	N840	3.0	4.1	4.1	2.5	3.5	1.9	3.4	6.2	3.0	1.8	2.6	1.7	1.5	9	11	11	16	1.6	1.0	9
	N459	3.0	3.8	3.8	2.4	3.4	1.8	3.4	6.9	3.0	1.9	2.7	1.7	1.3	10	11	11	16	1.6	1.0	9
	N460	2.9	3.9	3.8	2.4	3.7	1.8	3.9	5.3	2.9	1.8	2.8	1.6	1.2	11	13	11	17	1.8	1.0	9
	[1] N461	2.8	3.6	3.8	2.5	3.5	1.9	3.5	8.4	3.0	1.9	2.7	1.6	1.3	11	12	11	16	1.6	1.1	10

[1] University of Toronto collection.

TABLE 28.—*Records of the occurrence of Leucichthys zenithicus in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of zenithicus	Preserved specimens examined	
									+200 mm	−200 mm
Washington Harbor, Wis.	1	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay, mud	900	(1)		
Sturgeon Bay, Wis	2	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60–70	Mud	50	(1)	2	
Algoma, Wis	3	Aug. 24, 1920	10 miles E. by N	2½	35–50	Gravel, mud	310	20	2	
Sheboygan, Wis	4	Sept. 28, 1920	5 miles SE. by E	1½	30–32			(2)		7
	5	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	(3)	5	
Port Washington, Wis.	6	Sept. 25, 1920	18 miles E. ½ S	2½	65–48	do	285	(1)	7	
	7	do	5 miles E. ½ S	1½	30			(1)		2
	8	May 26, 1921	8 miles northeast	2½	20–35	Mud		(3)	2	
Milwaukee, Wis	9	Mar. 24, 1919		2½	50			(3)	3	
	10	Sept. 23, 1920	27 miles ESE	2½	60	Red clay	250	35	5	
	11	Sept. 24, 1920	9 miles NNE	2½	22–25	Clay		(3)	9	
	12	Nov. 15, 1920	20 miles ESE	2½	28–35		700	99	13	
	13	do	5 miles E. by S. ½ S	2½	12			(3)	2	
Michigan City, Ind	14	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30–40	Clay		29	11	
	15	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Mud, clay	535	44	5	
	16	Nov. 8, 1920	18 miles NNW	2½	30–38	Clay	1,000	54	11	
	17	Nov. 19, 1920	17 miles NNW	2½	28–32	do	700	15	6	
	18	do	10 miles NNW	2½	18			93	10	
	19	do	17½ miles NW. by N. ¾ N.	2½	32	Clay		70	3	
	20	Mar. 2, 1921	21 miles NNW	2½	30	do	1,000	(1)		
	21	Mar. 4, 1921	15 miles NW. by N. ½ N.	2½	28		1,000	(1)	3	
	22	Apr. 1, 1921		2½	30	Clay	500	(3)	2	
Grand Haven, Mich	23	Mar. 20, 1919	12 miles west	2¾	50–55	do		(3)	3	
Frankfort, Mich	24	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	6	2	
Northport, Mich	25	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40–60	Mud		(1)	5	
Charlevoix, Mich	26	June 29, 1920	5 miles N. by E	2¾	40–50	Clay, mud		(1)	2	
Manistique, Mich	27	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70		200	40	1	
Lake Michigan [4]								6	1	
Milwaukee, Wis.[5]								1		
Kenosha, Wis.[5]								1		
Sturgeon Bay, Wis.[6]								1		

1 Rare.
2 Occasional.
3 Lift not examined or percentage not ascertained.
4 Field Museum collection, borrowed specimens.
5 U. S. National Museum collection, borrowed specimens.
6 Wisconsin Geological Survey collection, borrowed specimens.

94995—29——19

TABLE 29.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys zenithicus from Lake Michigan over 200 millimeters long and for 7 specimens under 200 millimeters long, selected according to size and locality*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT
Over 200 millimeters	2828	Charlevoix, Mich.	280	13+25	♀	84	4.2	5.7	10.0	9.9	2.8	8.7
	2936	Manistique, Mich.	271	15+26	♀	79	4.3	5.7	10.4	11.1	2.8	8.7
	3992	Frankfort, Mich.	271	14+27	♀	84	4.1	5.4	10.2	10.5	3.0	9.3
	4208	Michigan City, Ind.	259	14+26	♀	73	4.1	5.7	8.9	9.8	2.8	8.3
	4332	do	252	15+26	♀	86	4.5	6.0	9.7	9.7	2.8	7.0
	4375	do	272	16+25	♀	87	4.3	5.9	10.2	9.7	2.9	7.5
	4379	do	271	14+25	♀	79	4.5	6.0	10.3	10.1	2.8	8.2
	4380	do	264	13+23	♀	81	4.3	5.8	9.4	10.1	2.7	8.3
	4386	do	245	16+26	♂	76	4.1	5.6	9.7	9.8	2.9	9.0
	4397	do	257	14+24	♂	75	4.1	5.5	9.1	9.1	3.0	8.8
Under 200 millimeters	3701	Port Washington, Wis.	175	14+23	Im. ♀	83	4.1	5.3	10.2	11.0	2.8	8.1
	3711	do	185	15+26	Im. ♂	84	4.2	5.6	10.8	8.8	2.8	7.9
	3777	Sheboygan, Wis.	171	13+26	Im. ♀	82	4.1	5.4	11.2	11.4	3.1	7.2
	3830	do	192	13+24	♂	74	4.0	5.4	9.6	10.2	2.8	7.8
	3852	do	170	14+24	Im. ♂	77	4.0	5.3	10.0	10.7	2.8	7.7
	3874	do	162	14+25	Im. ♂	80	4.0	5.5	9.5	10.0	2.7	7.3
	3881	do	168	15+24	Im. ♂	76	4.0	5.2	10.8	10.8	3.1	6.7

Size	Field No.	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R
Over 200 millimeters	2828	4.3	8.0	1.8	2.1	2.8	3.2	4.3	4.5	2.5	3.2	2.0	3.5	7.2
	2936	4.6	8.4	1.8	2.1	2.9	3.4	4.6	4.5	2.4	3.5	2.0	3.5	7.8
	3992	4.3	7.9	1.8	2.1	2.7	3.3	4.3	4.3	2.3	3.5	2.0	3.9	6.5
	4208	4.1	8.0	1.9	2.2	3.0	3.2	4.5	4.4	2.5	3.6	2.0	3.5	7.5
	4332	4.6	7.8	1.6	2.2	2.9	3.5	4.6	4.3	2.5	3.5	2.0	3.2	5.8
	4375	4.0	7.5	1.8	2.2	2.9	3.3	4.5	4.5	2.4	3.4	1.9	3.2	6.8
	4379	4.1	8.2	2.0	2.2	2.9	3.5	4.7	4.5	2.5	3.5	2.1	3.1	5.9
	4380	3.8	7.3	1.8	2.2	3.0	3.3	4.5	4.5	2.5	3.5	2.0	3.0	6.1
	4386	4.6	9.0	1.9	2.1	2.9	3.2	4.4	4.4	2.4	3.6	2.1	3.6	6.9
	4397	4.2	7.7	1.8	2.1	2.8	3.2	4.2	4.4	2.3	3.4	2.0	3.4	7.2
Under 200 millimeters	3701	4.6	9.7	2.1	2.0	2.5	3.2	4.0	4.1	2.6	3.5	2.0	4.1	6.0
	3711	4.5	10.2	2.2	2.1	2.8	3.1	4.1	4.2	2.6	3.6	2.1	3.6	6.2
	3777	5.3	9.5	1.7	2.0	2.6	3.1	4.1	4.0	2.5	3.5	2.0	3.4	6.6
	3830	4.4	10.6	2.3	2.1	2.8	3.1	4.1	4.2	2.6	3.5	2.0	3.4	7.2
	3852	4.7	10.0	2.1	2.0	2.7	3.0	4.0	4.0	2.7	3.6	2.1	3.5	6.3
	3874	5.2	9.0	1.7	2.0	2.8	3.0	4.2	4.2	2.7	3.6	2.0	3.3	6.6
	3881	5.2	11.2	2.1	1.9	2.5	3.0	3.9	4.1	2.6	3.5	2.1	3.2	6.1

Size	Field No.	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	MS/E
Over 200 millimeters	2828	3.3	1.9	2.4	2.1	1.6	10	12	11	17	1.5	0.98	9	3.1
	2936	3.3	1.9	2.6	2.0	1.6	10	11	10	15	1.6	1.1	9	3.0
	3992	3.3	1.7	2.7	2.2	1.8	10	10	11	15	1.4	.93	9	3.1
	4208	3.2	1.8	2.7	2.3	1.7	10	11	11	15	1.3	.95	9	2.8
	4332	3.2	1.9	2.6	2.1	1.7	9	11	11	15	1.4	.92	9	2.9
	4375	3.4	1.8	2.5	2.3	1.7	11	12	11	15	1.4	.93	9	3.1
	4379	3.4	1.9	2.6	2.4	2.0	11	11	11	15	1.3	.89	9	3.0
	4380	3.3	1.8	2.6	2.2	1.6	10	12	11	15	1.4	.96	9	3.0
	4386	3.2	1.7	2.6	2.1	1.4	10	11	11	15	1.5	.96	8	3.0
	4397	3.3	1.7	2.5	2.0	1.4	10	11	11	17	1.3	.91	9	3.1
Under 200 millimeters	3701	3.2	2.0	2.7	2.1	1.6	10	11	11	16	1.5	1.0	9	2.7
	3711	3.2	2.0	2.7	2.0	1.2	9	13	11	15	1.6	.96	9	2.7
	3777	3.0	1.9	2.7	2.0	1.5	10	10	11	14	1.6	1.1	8	2.7
	3830	3.2	2.0	2.7	2.0	1.3	10	10	11	15	1.5	1.1	8	2.8
	3852	3.0	2.0	2.7	2.0	1.3	10	11	11	14	1.6	1.0	8	2.6
	3874	3.0	1.9	2.5	1.9	1.3	9	11	11	16	1.5	1.0	9	2.7
	3881	3.1	2.0	2.6	1.9	1.3	10	11	11	15	1.8	1.1	9	2.7

TABLE 30.—*Records of the occurrence of Leucichthys zenithicus in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined	
									+200 mm.	−200 mm.
Lake Huron proper:										
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef.	2¾	35–50	Clay		(1)	8	3
	2	Sept. 28, 1917	2 miles northeast of Spectacle Reef.	2¾	35–50	do	1,800	99		
	3	Sept. 29, 1917	do	2¾	35–50	do	1,850	99	9	2
	4	Oct. 15, 1919		1½	35			(2)	1	11
Rogers, Mich.	5	July 24, 1917		2¾	60–70	Clay		(1)	5	
	6	Oct. 14, 1917	12 miles E. by N. ½ N. of city.	2¾	35–50	do	1,500	99	10	1
Alpena, Mich.	7	Aug. 13, 1917	38 miles east of can buoy	2¾	70–80	do	1,470	(1)	2	
	8	Sept. 7, 1917	Center of lake east of can buoy.	2¾	70–80	do	3,250	(3)	2	
	9	do	26 miles SE. by E. ¼ E. of can buoy.	4½	16–20			(4)	2	2
	10	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30			(5)	2	11
	11	Sept. 10, 1917	8 miles E. by N. of can buoy.	4½	20			(4)	1	
	12	do	13½ miles SE. by S. of can buoy.	4½	15	Mud		(4)	4	1
	13	Sept. 12, 1917	11 miles SE. ¾ E. of can buoy.	4½	15–17			(4)	2	2
	14	Sept. 14, 1917	24 miles SE. by E ½ E. of can buoy.	4½	24			(4)	2	1
	15	do	Center of lake northeast of can buoy.	2¾	65–80	Clay	1,200	(3)	1	1
	16	Sept. 17, 1917	13½ miles SE. by S. of can buoy.	2¾	15			(4)	1	
	17	do	Center of lake northeast of can buoy.	2¾	60–70	Clay		(3)	1	
	18	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60		825	(1)	5	3
	19	Sept. 19, 1917	23 miles SE. by E. ½ E. of can buoy.	2¾	30	Rock		(3)	1	
	20	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65	Clay		(1)		2
	21	Sept. 21, 1917	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–75	do		(1)		1
	22	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy.	4½	17			(4)	3	3
	23	Sept. 26, 1917	13 miles SE. by S. of can buoy.	2¾	17			(4)	1	
	24	Oct. 17, 1917	Center of lake east of can buoy.	2¾	65–80	Clay		(3)	1	
	25	Oct. 20, 1917	do	2¾	65–80	do		(3)	4	
	26	Aug. 30, 1919	18 miles N. by E. ½ E. of Thunder Bay Island.	2¾	60–64	do		17	2	
	27	Sept. 3, 1919	28 miles E. ¼ S. of can buoy.	2¾	60–64	do		17	2	
	28	Sept. 13, 1919	Off Presque Isle Light	1½	60			(4)		1
	29	Sept. 16, 1919		1½				(5)		1
	30	Aug. 7, 1920	19 miles NE. ½ N. of Thunder Bay Island.	2¾	60–65	Clay	3,500	3		
	31	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–70	do	1,600	5		1
	32	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60–70	do	2,000	3	4	
	33	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80–100	do	6,000	(3)	4	
	34	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60	do	1,400	14	4	1
	35	July 10, 1923	3 miles E. ½ S. of North Point.	4½	14–20	Rock, mud		(4)	1	1
Harbor Beach, Mich.	36	Oct. 27, 1917	35 miles NE. by N. ¾ N. of city.	2¾	50	Clay		(3)	3	
	37	Mar. 15, 1919		1½	31			12		30
Georgian Bay:										
Wiarton, Ontario	38	Nov. 6, 1917	6½ miles northeast of Griffith Island.	3	45–60	Mud		(1)	1	
Lion's Head, Ontario.	39	July 30, 1919	21 miles east of Surprise Shoal.	3	60	do	400	(4)		2
Borrowed specimens:										
Cheboygan, Mich.[6]									2	

[1] Lift not examined or percentage not ascertained.
[2] Occasional.
[3] Rare.
[4] Only specimens taken in the lift.
[5] Few.
[6] U. S. National Museum collection.

Table 31.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys zenithicus from Lake Huron, 10 of them more than 200 millimeters long and 10 less than 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	44	Cheboygan, Mich.	287	Im. ♂	14+25	72	4.1	5.7	10.0	11.0	2.6	9.2	3.8	9.2	2.4	2.1	2.9
	46	do	260	♀	14+26	71	4.1	5.5	8.8	9.5	2.7	9.4	4.1	9.6	2.3	2.1	2.8
	56	do	269	♀	14+25	80	4.5	6.2	9.9	10.0	2.5	8.4	4.0	7.9	1.9	2.2	3.0
	855	do	282	♀	14+25	75	4.3	5.8	9.7	10.4	2.6	7.2	3.8	6.9	1.8	2.1	2.9
	856	do	275	♀	14+24	82	4.1	5.7	10.5	9.8	2.7	8.0	3.5	6.4	1.8	2.1	3.0
	942	Rogers, Mich.	257	♀	13+23	74	4.2	5.8	9.5	9.3	2.7	8.2	3.5	8.5	2.3	2.0	2.9
	224	Alpena, Mich.	236	♂	14+23	77	4.1	5.6	10.0	10.0	2.8	7.3	4.9	9.0	1.8	2.0	2.7
	423	do	277	♂	14+26	81	4.4	6.2	9.8	9.0	2.8	8.9	5.1	9.3	1.8	2.1	3.0
	433	do	261	Evis.	14+27	82	4.2	5.7	9.5	9.8	2.7	8.0	4.4	9.3	2.1	2.1	2.9
	540	do	270	Evis.	13+24	72	4.2	6.0	9.3	10.8	2.8	7.9	4.3	9.3	2.1	2.1	2.9
Under 200 millimeters.	58	Cheyboygan, Mich.	186	Im. ♀	13+25	77	4.1	5.5	9.9	9.5	3.1	8.7	4.8	10.0	2.0	2.1	2.8
	841	do	167	♀	13+22	79	4.2	5.7	9.8	9.9	2.9	8.3	3.9	.77	1.9	2.1	2.9
	897	do	191	♀	13+23	82	4.1	5.4	10.4	10.9	2.8	7.6	3.8	7.7	2.0	2.1	2.7
	230	Alpena, Mich.	191	♂	14+23	79	4.2	5.8	11.2	11.2	2.9	8.2	4.7	8.7	1.8	2.1	3.0
	249	do	167	Im. ♀	12+23	74	4.1	5.6	11.5	9.8	3.0	8.0	4.5	8.0	1.7	2.1	2.8
	253	do	188	Im. ♀	14+25	78	4.2	5.7	9.0	10.3	2.7	9.6	4.2	8.1	1.9	2.1	2.9
	255	do	170	Im. ♀	13+24	77	4.1	5.7	9.4	9.8	2.8	8.2	4.3	8.5	1.9	2.0	2.7
	269	do	171	Im. ♂	13+23	75	4.0	5.7	9.4	9.5	2.8	8.2	4.8	9.0	1.8	2.0	2.8
	270	do	180	Im. ♂	14+24	80	4.0	5.7	9.2	10.0	2.8	8.2	4.5	8.7	1.9	2.0	2.9
	273	do	190	Im. ♂	14+26	79	4.2	5.8	10.5	9.1	2.8	8.6	4.5	10.0	2.2	2.1	2.9

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	44	3.2	4.4	4.6	2.5	3.3	2.1	4.0	6.8	3.3	1.8	2.4	2.0	1.5	9	10	10	16	1.4	0.93	9
	46	3.3	4.4	4.4	2.6	3.4	2.0	4.0	6.8	3.3	1.9	2.5	2.1	1.5	11	11	11	16	1.3	.96	9
	56	3.4	4.8	4.4	2.5	3.5	2.1	3.5	7.0	3.1	1.8	2.5	1.9	1.5	10	10	12	17	1.5	1.0	9
	855	3.3	4.4	4.4	2.3	3.4	2.0	3.8	6.0	3.2	1.7	2.5	2.1	1.6	10	11	12	17	1.3	.92	10
	856	3.2	4.4	4.7	2.4	3.3	2.0	3.4	6.4	3.3	1.7	2.3	2.0	1.6	10	11	11	16	1.5	.93	9
	942	3.3	4.5	4.5	2.4	3.3	2.0	3.1	6.6	3.2	1.7	2.4	2.0	1.5	10	11	11	17	1.4	.86	8
	224	3.1	4.2	4.4	2.5	3.5	2.0	3.8	6.5	3.2	1.8	2.6	1.8	1.5	10	11	11	17	1.5	1.0	9
	423	3.4	4.8	4.4	2.5	3.3	2.0	3.8	5.5	3.2	1.8	2.4	1.9	1.5	10	12	11	16	1.5	.93	8
	433	3.2	4.4	4.2	2.5	3.4	2.1	3.5	7.6	3.1	1.8	2.5	2.1	1.6	10	12	11	17	1.3	.93	9
	540	3.4	4.7	4.2	2.5	3.7	2.1	3.7	5.6	3.0	1.8	2.6	2.0	1.6	10	11	11	16	1.4	1.0	9
Under 200 millimeters.	58	3.2	4.3	3.7	2.6	3.6	2.0	3.7	6.9	2.8	1.9	2.9	2.1	1.4	9	11	11	17	1.5	1.0	9
	841	3.2	4.4	4.1	2.8	3.5	2.0	3.4	7.5	3.0	2.0	2.6	2.4	1.4	10	11	11	16	1.5	.98	9
	897	3.1	4.1	4.0	2.6	3.5	2.0	3.8	11.7	3.0	2.0	2.7	2.2	1.4	10	11	11	16	1.5	.97	8
	230	3.2	4.4	4.0	2.6	3.5	2.1	3.3	6.4	2.9	1.8	2.6	2.1	1.5	10	10	10	16	1.6	1.0	9
	249	3.3	4.4	3.7	2.6	4.0	2.1	3.8	6.4	2.7	1.9	2.9	2.3	1.5	9	11	11	17	1.6	1.0	9
	253	3.2	4.4	4.2	2.5	3.5	2.2	4.1	6.8	3.0	1.8	2.6	2.0	1.6	11	11	11	16	1.3	.98	9
	255	3.1	4.3	4.1	2.5	3.6	2.1	4.0	6.0	3.9	1.9	2.6	1.8	1.5	10	12	11	17	1.4	.92	9
	269	3.1	4.3	4.1	2.5	3.7	2.0	3.8	6.4	3.0	1.9	2.6	1.9	1.4	10	11	11	16	1.4	.94	10
	270	3.1	4.4	4.1	2.6	3.7	2.1	4.0	6.5	2.9	1.8	2.6	1.9	1.5	10	12	11	17	1.4	1.0	9
	273	3.3	4.5	4.2	2.5	3.6	2.1	3.8	6.5	3.0	1.8	2.6	2.0	1.6	9	11	11	16	1.6	.96	9

TABLE 32.—*Records of the occurrence of Leucichthys reighardi in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of reighardi	Preserved specimens examined	
									+200 mm.	−200 mm.
Washington Harbor, Mich.	1	Aug. 18, 1920	4 miles west of Boyer Bluff.	2⅝	18–24			[1]	7	
	2	do	14 miles E. ¾ N. of Rock Island.	2½	30–50			[2]	1	
	3	do	5 miles west of Boyer Bluff.	4	20	Rock		[3]		3
	4	do	3 miles WNW. of Boyer Bluff.	4	20–24			[1]	1	
	5	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay-mud	900	[1]	1	1
Sturgeon Bay, Wis.	6	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60–70	Mud	50	[1]	3	
Algoma, Wis.	7	Aug. 24, 1920	10 miles E. by N.	2½	35–50	Gravel-mud	310	[4]	12	4
Sheboygan, Wis.	8	Sept. 28, 1920	40 miles SE. by E.	3½	35–40				3	1
	9	do	5 miles SE. by E.	1½	30–32			20	1	31
	10	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	[2]	12	
Port Washington, Wis.	11	Sept. 25, 1920	18 miles E. ½ S.	2½	65–48	do	285	[1]	4	2
	12	do	5 miles E. ½ S.	1½	30			[4]		
	13	May 26, 1921	8 miles northeast	2½	20–35	Mud		[2]	8	
Milwaukee, Wis.	14	Mar. 24, 1919		2½	50			[2]	2	
	15	Sept. 23, 1920	27 miles ESE.	2½	60	Red clay	250	[1]	2	
Racine, Wis.	16	Oct. 8, 1920		1½	30	Clay		[2]		
Michigan City, Ind.	17	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30–40	do		[1]	4	
	18	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Mud-clay	535	[1]	15	
	19	Nov. 8, 1920	18 miles NNW.	2½	30–38	Clay	1,000	[1]	6	1
	20	Nov. 19, 1920	17 miles NNW.	2½	28–32		700	[4]	8	
	21	Nov. 19, 1920	17½ miles NW. by N. ¾ N.	2½	32	Clay		[4]		
	22	Mar. 2, 1921	21 miles NNW.	2½	30	do	1,000	16		
	23	do	14 miles NNW.	1½	26	do		[1]		3
	24	Mar. 4, 1921	15 miles NW. by N. ½ N.	2½	28		1,000	[1]	8	
	25	Apr. 1, 1921		2½	30	Clay	500	30	47	
Grand Haven, Mich.	26	Mar. 20, 1919	12 miles west	2¾	50–55	do		[2]	6	1
Ludington, Mich.	27	Aug. 30, 1920	7 miles NW. by N.	4½	14–26			[3]	1	
Manistee, Mich.	28	Aug. 27, 1920	4 miles west	1½	28–35			[2]		3
	29	Aug. 28, 1920	9 miles northwest	4½	28–32			[1]	1	
Frankfort, Mich.	30	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	[1]	4	1
Platte Bay, Mich. (field station).	31	July 21, 1923	1½ miles south of Otter Creek.	1½	8–12	Sand		[1]		
Northport, Mich.	32	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40–60	Mud	200	[1]	8	
	33	June 23, 1920	Off Northport Point	1½	28–40	do		30		48
	34	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40–60	do		41	92	2
Traverse City, Mich.	35	July 18, 1923	West Bay	1½	30–40	Clay				
	36	July 25, 1923	Off Lees Point	1½	6–16			[3]	1	3
Charlevoix, Mich.	37	June 29, 1920	5 miles N. by E.	2¾	40–55	Clay-mud		[1]	9	
	38	June 30, 1920	3 miles northwest	2¾	40–65	Clay		[2]	1	1
	39	Aug. 10, 1923	8 miles NNW. of Big Rock Point.	2¾	45–50	do	480	[4]		
	40	Aug. 11, 1923	3 miles NW. ½ W.	2¾	35–60	Red clay	375	21	35	
	41	Aug. 21, 1923					100	[4]	3	
	42	May 3, 1924		2¾					43	
Manistique, Mich.	43	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70		200	[4]	5	1

[1] Rare.
[2] Lift not examined or percentage not ascertained.
[3] Only specimens taken in lift.
[4] Occasional.

TABLE 33.—*Numerical expressions of certain systematic characters for the type of Leucichthys reighardi and for 9 other specimens from Lake Michigan, 4 of them cotypes, over 200 millimeters long and for 10 other specimens under 200 millimeters long, selected according to size and locality*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	[1]87351	Michigan City, Ind.	210	14+23	♀	74	4.4	6.0	10.9	9.9	3.1	7.2	4.2	6.7	1.6	2.3	3.1
	53080	do	223	14+25	♂	75	4.2	5.4	9.4	9.7	2.6	6.9	4.1	6.9	1.6	2.1	2.7
	53094	do	220	14+24	♀	77	4.4	5.9	11.2	9.6	2.9	7.5	4.4	7.3	1.6	2.2	2.9
	53104	do	234	13+22	♀	76	4.4	5.8	9.7	11.0	2.8	6.9	3.9	6.9	1.7	2.3	3.0
	53111	do	233	13+23	♀	75	4.3	5.8	10.0	10.0	2.7	7.0	4.0	6.6	1.6	2.1	2.9
	4684	Charlevoix, Mich.	226	14+22	♀	75	4.2	5.6	9.8	9.8	2.8	5.7	4.2	7.2	1.7	2.1	2.8
	4685	do	240	14+23	♀	71	4.6	5.9	10.0	9.4	3.0	7.5	4.1	7.5	1.8	2.3	3.0
	4686	do	238	13+24	♀	73	4.2	5.6	9.8	9.0	2.8	8.8	3.8	6.6	1.7	2.1	2.9
	4687	do	227	12+22	♀	74	4.2	5.5	9.0	9.8	2.9	7.5	4.3	7.5	1.7	2.0	2.7
	4688	do	233	13+22	♀	81	4.3	5.7	10.4	10.9	2.9	8.3	4.3	7.2	1.6	2.2	2.9
Under 200 millimeters.	3375	Manistee, Mich.	161	14+23	Im. ♂	73	4.2	5.6	10.5	8.9	2.9	8.9	4.2	10.5	2.1	2.1	2.8
	3376	do	166	14+26	♀	80	4.2	5.6	11.2	9.7	3.1	7.4	4.7	9.7	2.0	2.1	2.8
	3656	Port Washington, Wis.	182	14+25	♂	76	4.1	5.3	9.6	9.1	3.0	7.2	4.3	9.1	2.1	2.1	2.7
	3781	Sheboygan, Wis.	198	14+22	♂	79	4.6	6.2	11.3	9.0	3.0	7.3	4.7	8.4	1.7	2.2	3.0
	3786	do	186	13+21	♂	78	4.4	6.0	11.4	10.0	2.9	7.9	4.7	10.0	2.1	2.1	2.9
	3822	do	168	13+23	♀	68	4.4	6.0	11.2	11.0	3.1	8.0	4.4	9.3	2.1	2.2	3.0
	3825	do	191	13+23	♂	75	4.2	5.6	10.6	9.6	2.9	8.6	4.5	9.5	2.1	2.1	2.8
	3854	do	172	13+22	♂	74	4.4	5.9	10.1	10.1	2.9	8.0	4.1	10.1	2.4	2.1	2.8
	3856	do	183	14+23	♂	77	4.5	6.2	10.7	9.6	2.9	7.6	4.5	9.1	2.0	2.2	3.0
	4656	Michigan City, Ind.	172	13+23	♀	77	4.3	5.7	10.1	9.4	2.9	7.7	4.3	7.1	1.6	2.1	2.8

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters.	[1]87351	3.4	4.6	3.8	2.7	3.8	2.1	3.1	6.7	2.8	2.0	2.8	2.1	1.4	9	10	11	16	1.6	1.0	9
	53080	3.1	3.9	4.0	2.6	3.7	2.1	3.2	6.5	3.1	2.0	2.9	2.0	1.5	9	11	10	16	1.4	1.0	9
	53094	3.5	4.6	4.1	2.8	3.7	2.1	3.7	5.9	3.1	2.1	2.8	2.3	1.7	9	11	11	16	1.5	.92	10
	53104	3.3	4.5	4.3	2.6	3.7	2.1	3.3	6.6	3.2	2.0	2.8	2.4	1.6	9	10	10	16	1.3	.90	10
	53111	3.2	4.3	4.1	2.7	3.8	2.1	3.3	6.7	3.0	2.0	2.8	2.1	1.7	10	11	12	17	1.4	.95	9
	4684	3.3	4.3	4.1	2.7	3.8	2.1	3.2	5.1	3.1	2.0	2.8	2.0	1.5	10	12	11	16	1.5	1.0	8
	4685	3.5	4.5	3.9	2.7	3.6	2.0	3.0	6.1	3.0	2.0	2.8	2.2	1.5	9	11	11	16	1.4	.90	9
	4686	3.3	4.4	4.0	2.8	3.8	2.1	3.6	6.0	3.0	2.1	2.8	2.3	1.5	10	11	12	15	1.3	.90	9
	4687	3.3	4.3	4.0	2.7	3.6	2.0	3.3	7.0	3.1	2.0	2.7	2.0	1.6	9	12	11	16	1.4	.86	9
	4688	3.5	4.6	4.0	2.8	3.7	2.1	3.7	5.4	3.1	2.1	2.8	2.5	1.6	9	11	12	16	1.4	1.0	9
Under 200 millimeters.	3375	3.1	4.1	3.8	2.6	3.7	2.1	3.4	6.0	2.9	2.0	2.8	2.0	1.4	9	11	11	16	1.6	.84	9
	3376	3.2	4.3	3.8	2.7	4.1	2.0	3.2	5.6	2.8	2.0	3.1	2.3	1.4	9	11	10	16	1.7	.92	8
	3656	3.1	4.0	3.8	2.5	3.6	2.0	3.1	5.5	2.9	2.0	2.8	1.9	1.2	9	11	11	16	1.6	1.0	8
	3781	3.4	4.6	4.0	2.6	3.9	2.0	3.0	6.1	3.0	1.9	2.9	2.4	1.5	9	11	11	16	1.6	.86	8
	3786	3.3	4.5	3.9	2.7	3.8	2.1	3.7	6.9	2.9	2.0	2.8	2.2	1.7	9	11	11	15	1.6	.91	9
	3822	3.5	4.7	3.8	2.8	4.0	2.1	3.7	6.3	2.8	2.0	2.9	2.1	1.6	10	10	11	15	1.7	1.1	9
	3825	3.3	4.4	3.9	2.8	4.0	2.1	4.0	6.9	2.9	2.1	3.0	2.0	1.5	9	11	11	17	1.5	1.0	9
	3854	3.3	4.4	3.9	2.7	3.6	2.0	3.5	6.2	2.9	2.0	2.7	2.3	1.6	10	11	11	15	1.4	.95	8
	3856	3.2	4.4	3.8	2.7	4.3	2.0	3.3	5.8	2.7	1.9	3.1	2.0	1.4	9	11	11	17	1.6	1.1	9
	4656	3.2	4.3	4.0	2.8	4.0	2.1	3.7	6.4	3.0	2.1	3.0	2.2	1.6	10	11	10	16	1.5	.94	9

[1] Type, U. S. National Museum number.

TABLE 34.—*Records of the occurrence of Leucichthys reighardi dymondi in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined	
					+200 mm.	−200 mm.
1	Aug. 9, 1921	Off Macdiarmid		10–15	1	2
2	July 26, 1922	do	2½, 2¾	30	35	1
3	Aug. 4, 1923	do		7	2	
4	Sept. 8, 1923	do		6		1
5	Sept. 10, 1923	do				1
6	Sept. 6, 1923	Off Selwyn Island				1
7	Sept. 3, 1923	Humboldt Bay		6–35	2	1
8	Sept. 5, 1923	Off McKellar Island			1	1
9	June 19, 1924	Ombabika Bay		10	1	
10	Aug. 17, 1921	Off Whitesand River		25	3	1
11	June 30, 1921	Off Frog Island		25		1
12	Aug. 23, 1921	Grand Bay		10		1
13	Aug. 1, 1922	do	4½	15–20	1	1
14	July 17, 1924	do		20	2	
15	Aug. 25, 1921	Off source of Nipigon River		12	3	
16	July 25, 1922	do	2½, 2¾	10–15	27	1
17	July 19, 1924	do		15	4	
18	Aug. 27, 1921	Sandy Bay		5–8	1	2
19	July 23, 1924	do		11	2	
20	Aug. 15, 1922	Unknown		20–25	1	
21	Oct. 26, 1922	do	4½		3	2

[1] All but records 2, 13, 16, and 21 are from University of Toronto collections.

TABLE 35.—*Numerical expressions of certain systematic characters for the type of the dymondi form of Leucichthys reighardi from Lake Nipigon and for 17 cotypes, half over 200 millimeters and half under 200 millimeters long, selected according to size*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 millimeters.	57273	Nipigon River source.	211	13+22	♀	72	3.9	5.1	8.7	9.5	2.7	7.8	3.8	8.1	2.1	1.9	2.5
	57301	do	238	12+22	♂	73	3.9	4.8	8.8	9.0	3.0	8.0	4.0	8.8	2.1	2.0	2.4
	57304	do	268	13+21	♂	71	3.9	5.1	9.7	9.9	2.9	7.4	3.8	9.2	2.4	2.0	2.6
	57309	do	261	12+21	♂	68	3.8	5.1	8.0	9.0	2.9	8.7	3.7	8.4	2.2	1.9	2.5
	[1] 57467	Macdiarmid, Ontario.	227	12+20	♀	69	3.7	4.9	9.0	9.1	2.9	8.4	3.8	8.7	2.2	1.8	2.4
	57499	do	225	12+23	♂	71	4.0	5.1	8.3	8.2	2.8	9.3	3.8	8.3	2.1	1.9	2.5
	57501	do	238	13+22	♀	70	3.7	5.1	8.5	8.5	3.0	7.6	3.9	8.8	2.2	1.9	2.6
	57595	do	223	13+22	♀	64	3.5	4.6	9.6	9.7	3.0	8.2	3.7	8.2	2.2	1.8	2.4
	57657	do	225	13+21	♀	70	3.7	5.1	9.6	8.8	2.7	9.0	3.7	8.0	2.1	1.9	2.6
Under 200 millimeters.	57267	Nipigon River source.	197	13+23	♂	68	3.6	4.6	8.7	8.2	2.7	7.8	3.9	8.5	2.1	1.8	2.4
	57667	Macdiarmid, Ontario.	169	13+21	Im. ♂	71	3.8	4.9	8.6	8.8	2.8	8.0	4.1	8.8	2.1	1.9	2.5
	57721	do	200	13+23	Im. ♀	74	3.9	5.0	10.5	9.5	2.9	8.6	4.3	9.3	2.1	2.0	2.6
	63069	(?)	190	11+21	♂	67	3.9	5.0	9.5	9.5	3.0	8.2	4.2	7.0	1.6	1.9	2.5
	63076	(?)	195	13+21	♀	70	3.7	4.7	8.8	9.2	2.9	7.8	3.8	6.7	1.7	1.9	2.3
	N70	Orient Bay	181	12+23	♂	66	3.6	5.0	8.9	9.5	2.9	8.6	3.9	9.0	2.3	1.8	2.5
	N105	Sandy Bay	185	13+22	♀	72	3.9	5.4	10.0	9.8	2.9	7.4	4.0	9.2	2.3	1.9	2.6
	N1019	Humboldt Bay.	175	13+22	♂	73	3.9	5.1	9.7	10.1	2.9	8.3	3.8	9.2	2.3	2.0	2.5
	N1077	Orient Bay	145	13+21	Im. ♀	74	3.6	4.8	10.3	10.2	3.0	7.6	4.8	9.0	1.8	1.8	2.4

[1] Type, U. S. National Museum No. 88353.

TABLE 35.—*Numerical expressions of certain systematic characters for the type of the dymondi form of Leucichthys reighardi from Lake Nipigon and for 17 cotypes, half over 200 millimeters and half under 200 millimeters long, selected according to size*—Continued

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 milli-	57273	3.0	3.9	4.0	2.6	3.5	1.8	3.1	5.3	3.1	2.0	2.7	1.7	1.6	11	11	10	15	1.4	1.1	9
meters.	57301	3.0	3.7	4.0	2.4	3.5	2.0	3.3	5.3	3.2	1.9	2.8	1.7	1.3	11	12	11	16	1.6	1.1	9
	57304	3.0	3.9	4.5	2.5	3.5	1.9	3.0	5.6	3.4	1.9	2.7	1.6	1.3	11	12	11	16	1.7	1.1	9
	57309	3.0	4.0	4.4	2.5	3.6	2.0	3.3	6.5	3.4	1.9	2.8	1.5	1.6	11	11	11	15	1.4	1.0	9
	[1] 57467	2.9	3.9	4.2	2.3	3.5	1.9	3.2	5.0	3.2	1.7	2.6	1.6	1.5	10	12	11	16	1.5	1.0	9
	57499	3.1	4.0	4.0	2.5	3.4	1.9	3.5	6.0	3.1	1.9	2.6	1.8	1.6	11	12	11	16	1.4	.96	9
	57501	2.9	4.0	4.2	2.5	3.6	1.9	4.0	5.6	3.1	1.8	2.6	1.9	1.5	11	12	11	16	1.5	.99	10
	57595	2.8	3.7	4.1	2.4	3.6	1.9	3.4	5.6	3.2	1.9	2.7	1.8	1.5	10	11	11	16	1.6	1.0	10
	57657	2.9	4.0	4.0	2.5	4.0	2.0	3.6	5.8	2.9	1.9	2.9	1.5	1.5	9	11	11	16	1.6	1.0	10
Under 200 milli-	57267	2.8	3.7	3.8	2.4	3.6	1.8	3.3	4.8	3.0	1.8	2.8	1.6	1.4	10	11	11	16	1.6	1.0	9
meters.	57667	2.9	3.7	3.7	2.4	3.7	1.8	3.6	5.6	2.8	1.8	2.8	1.5	1.4	10	12	11	17	1.6	1.0	9
	57721	3.0	4.0	3.9	2.4	3.6	1.9	3.9	5.3	3.0	1.8	2.8	1.7	1.4	10	10	11	16	1.9	1.1	10
	63069	3.1	3.7	3.9	2.4	3.6	1.9	3.2	5.1	3.1	1.8	2.8	1.5	1.5	10	11	10	15	1.8	1.1	9
	63076	3.0	3.8	3.7	2.3	3.4	1.8	3.6	5.0	3.0	1.9	2.7	1.8	1.5	10	10	11	16	1.5	1.0	9
	N70	2.8	3.8	4.0	2.4	3.8	2.0	3.5	4.8	2.9	1.8	2.8	1.6	1.4	10	11	11	16	1.4	1.1	9
	N105	3.0	4.1	3.9	2.5	3.9	1.9	3.0	5.7	2.8	1.8	2.8	1.8	1.5	10	12	11	16	1.9	1.1	8
	N1019	3.0	4.0	3.7	2.5	3.7	1.9	3.6	5.1	2.8	1.9	2.8	1.8	1.4	10	10	11	15	1.8	1.1	10
	N1077	2.8	3.7	3.7	2.6	3.7	2.0	3.5	5.1	2.7	1.9	2.7	1.6	1.3	9	10	11	16	2.0	1.2	10

[1] Type, U. S. National Museum No. 88353.

TABLE 36.—*Records of the occurrence of Leucichthys reighardi dymondi in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, the abundance of this species in the lift, and the number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Percentage of reighardi	Preserved specimens examined, +200 mm.
Ontonagon, Mich.	1	Aug. 24, 1921	21 miles west	2½, 2¾	15–45	Red clay	(1)	4
	2	Aug. 25, 1921	6 miles NNW	2½, 2¾	20–38	Sand, clay	(1)	1
Apostle Islands, Wis.	3	July 11, 1922	Between Cat and South Twin Islands.	2½, 2¾	15–20	Sand	(1)	2
Duluth, Minn.	4	July 17, 1922	20 miles NE. by E.	2⅝	30–40	do	(2)	
Grand Marais, Minn.	5	Sept. 14, 1921	Off Terrace Point	2½, 2¾	30–65	Clay	(1)	2
Port Arthur, Ontario.	6	July 20, 1922	Black Bay	(3)	8	Mud	(1)	3
	7	Nov. 25, 1922	Thunder Bay, between Pie and Welcome Islands.	2½			(4)	199
	8	Sept. 15, 1923	North of Silver Island	2½	14	Mud	65	21
	9	do	Thunder Bay, off Thunder Cape.	2½	31	Brownish-gray clay.	50	33
	10	Sept. 17, 1923	Thunder Bay, north of Welcome Islands.	2½	11	do	81	14
	11	do	Thunder Bay, south of Welcome Islands.	2½	23	Clay	92	28
	12	Sept. 19, 1923	Thunder Bay, off Sawyer Bay.	2½	49	Brownish-gray clay.	32	15
Rossport, Ontario.	13	Mar. 10, 1922		2½			(4)	1
	14	Aug. 5, 1922	Moffat Strait	(3)	4		(1)	7
	15	do	Armour Harbor	(3)	4		(1)	1
	16	Aug. 10, 1922	Moffat Strait	(3)	4		(1)	5
	17	do	Crow Point	(3)	4		(1)	1
	18	Sept. 25, 1923	Moffat Strait	2½	13–14	Clay, sand	17	5
	19	Sept. 29, 1923	Off Salter Island	2½	42	Clay	(1)	4

[1] Only specimens taken in lift. [2] Rare. [3] Pound net. [4] Lift not examined.

TABLE 37.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys reighardi dymondi from Lake Superior, selected at random*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
59139	Port Arthur, Ontario	225	13+23	♂	68	4.0	5.5	9.7	8.6	2.8	8.5	4.2	7.7	1.8	1.9	2.6	3.0
59162	do	215	14+23	♀	68	3.9	5.5	9.6	9.7	2.9	7.4	3.7	7.6	2.0	1.9	2.7	3.0
59174	do	235	13+24	♂	72	4.1	5.8	10.9	10.6	2.6	7.1	4.4	8.3	1.8	2.0	2.8	3.2
59180	do	223	13+21	♂	69	3.9	5.3	8.5	9.7	2.7	7.1	4.3	7.1	1.6	2.0	2.6	2.9
59181	do	223	13+24	♀	73	4.0	5.3	9.6	8.9	2.6	7.3	4.1	8.2	2.0	1.8	2.4	3.0
59186	do	217	13+23	♂	71	3.8	5.2	9.8	9.0	2.9	7.9	3.9	7.4	1.8	1.9	2.6	3.0
59197	do	222	12+24	♀	74	3.8	5.1	8.7	10.0	2.7	8.5	4.0	8.2	2.0	2.0	2.6	2.9
59198	do	235	13+21	♀	74	4.1	5.5	9.4	9.8	2.7	7.5	4.1	8.7	2.1	2.0	2.7	3.1
59208	do	211	13+21	♂	73	4.0	5.3	8.7	8.3	2.8	9.1	3.9	7.5	1.9	2.0	2.6	3.1
59218	do	237	12+23	♂	73	3.8	5.6	9.1	8.5	2.8	8.7	4.0	7.4	1.8	1.9	2.7	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
59139	Port Arthur, Ontario	4.1	4.0	2.5	3.7	2.1	3.5	6.3	2.9	1.8	2.7	1.8	1.5	10	12	11	16	1.6	0.89	9
59162	do	4.2	3.9	2.6	4.1	2.0	3.8	5.5	2.8	1.8	2.9	1.7	1.5	11	12	12	16	1.7	1.0	9
59174	do	4.5	4.0	2.5	3.8	2.0	3.5	5.6	2.8	1.8	2.7	1.9	1.4	11	12	12	17	1.8	1.0	10
59180	do	3.9	3.9	2.5	3.8	2.0	3.2	5.5	2.9	1.9	2.8	1.7	1.4	11	11	11	17	1.4	1.0	9
59181	do	4.0	4.1	2.5	3.7	2.0	4.2	5.6	3.0	1.8	2.8	2.0	1.5	10	13	12	17	1.4	.86	10
59186	do	4.1	4.1	2.4	3.6	2.1	3.7	5.9	3.0	1.8	2.7	1.7	1.3	11	12	11	15	1.7	1.0	9
59197	do	3.9	4.0	2.5	3.5	2.0	4.0	5.7	3.0	1.8	2.6	1.8	1.3	10	11	11	14	1.4	1.0	9
59198	do	4.3	4.0	2.5	3.8	2.0	3.6	5.7	3.0	1.8	2.8	1.9	1.5	10	12	11	15	1.4	.91	9
59208	do	4.1	3.9	2.5	3.7	2.0	3.6	5.7	2.9	1.9	2.8	1.8	1.6	10	11	12	17	1.4	1.0	8
59218	do	4.4	4.3	2.5	4.0	2.1	4.0	5.4	3.0	1.7	2.7	1.6	1.6	10	12	11	16	1.4	.92	9

TABLE 38.—*Records of the occurrence of Leucichthys reighardi in Lake Ontario*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the abundance of this species in the lift, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Brighton, Ontario	1	June 10, 1921	20 miles S. by W. from the light.	2½	40–50	Mud	Common	18	
	2	June 16, 1921	do	2½	40–50	do	do	16	
Sandy Pond, N. Y.	3	Aug. 24, 1923	9 miles west	3	25–30	do	Occasional	13	
	4	Aug. 30, 1923	14 miles west	2½, 3½	60	Clay and mud.	do	10	
Selkirk, N. Y.	5	July 11, 1921	5 miles NNW. off Nine-Mile Point.	3	25–35	Blue clay	Rare	4	
Oswego, N. Y.	6	Sept. 1, 1923	Off Nine-Mile Point	3	30	Brown clay	Common	1	
Sodus Point, N. Y.	7	July 12, 1921	8½ miles NNW	2½, 2¾	60	Mud and clay.	Rare	3	
Charlotte, N. Y.	8	July 4, 1921	7 miles off Braddock Point Light.	2½, 2¾	65	Blue and brown clay	do	1	
Wilson, N. Y.	9	June 23, 1921	3 miles north	2½, 2¾	30	Brown clay	do	2	
	10	July 19, 1921	6½ miles N. by W. ½ W.	2½, 2¾	65	do	do	2	
	11	July 21, 1921	2 miles north	2½	20		Common	6	2

TABLE 39.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys reighardi from Lake Ontario, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O
53166	Brighton, Ontario	225	13+25	♂	85	4.7	6.4	9.6	10.0	2.8	7.7	4.5	9.0	1.9	2.3	3.1	3.7	4.9
53179	do	228	12+22	♂	80	4.6	6.1	9.9	9.8	2.9	7.3	4.6	8.7	1.8	2.2	3.0	3.5	4.7
53934	do	216	13+23	♂	76	4.5	6.3	9.7	9.1	2.7	7.4	4.4	8.6	1.9	2.3	3.1	3.5	4.8
53937	do	240	14+23	♀	76	4.7	6.4	10.3	10.0	2.7	8.0	4.2	8.0	1.9	2.4	3.3	3.6	4.9
53942	do	215	14+23	♂	75	4.3	5.9	10.2	9.3	3.0	7.6	4.0	7.6	1.8	2.0	2.7	3.4	4.7
53952	do	240	12+21	♂	74	4.5	6.1	10.4	10.9	2.7	8.0	4.1	8.5	2.0	2.3	3.2	3.4	4.7
53956	do	257	13+23	♂	78	4.6	6.4	10.7	9.1	2.8	8.2	3.7	7.3	1.9	2.3	3.2	3.7	5.1
53982	Wilson, N. Y.	208	14+24	♀	72	4.3	5.9	10.9	9.5	2.8	7.1	4.3	7.4	1.7	2.2	3.0	3.3	4.5
53996	do	203	14+24	♀	80	4.5	6.0	10.5	9.2	2.9	7.8	4.6	7.2	1.5	2.2	2.9	3.5	4.7
54080	do	240	13+24	♂	75	4.6	5.9	10.5	9.5	2.8	8.4	4.0	7.5	1.8	2.4	3.1	3.4	4.5

Field No.	Locality	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53166	Brighton, Ontario	4.2	2.8	3.9	2.1	3.3	5.7	3.1	2.1	2.9	2.5	1.8	11	10	11	15	1.2	0.92	9
53179	do	4.1	2.8	3.8	2.2	2.7	7.9	3.1	2.1	2.8	2.2	1.6	11	11	11	16	1.4	1.0	9
53934	do	4.0	2.9	3.6	2.1	3.1	6.7	2.9	2.1	2.6	2.3	1.5	10	12	11	17	1.4	.89	7
53937	do	4.2	2.8	3.8	2.1	4.2	7.0	3.1	2.0	2.8	2.7	1.5	10	11	11	17	1.4	1.0	9
53942	do	4.2	2.9	4.0	2.1	3.2	6.1	3.1	2.1	3.0	2.3	1.7	9	11	11	15	1.4	.94	9
53952	do	4.4	2.8	3.7	2.3	3.3	7.0	3.2	2.0	2.7	2.1	1.4	9	9	11	16	1.6	1.1	8
53956	do	4.2	2.7	3.9	2.1	3.6	7.6	3.0	2.0	2.8	2.3	1.6	8	11	12	16	1.5	.96	9
53982	Wilson, N. Y.	4.2	2.9	4.2	2.1	3.4	6.8	3.1	2.1	3.1	2.3	1.5	9	12	10	16	1.6	.96	8
53996	do	4.2	2.8	3.7	2.1	3.1	6.5	3.0	2.1	2.8	2.4	1.6	11	12	10	16	1.4	.90	9
54080	do	4.3	2.6	3.4	2.1	3.2	6.4	3.3	2.0	2.6	2.4	1.4	9	10	11	15	1.4	.90	8

TABLE 40.—*Records of the occurrence of Leucichthys nigripinnis in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of nigripinnis	Preserved specimens examined
Washington Harbor, Wis.	1	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay, mud.	900	(1)	2
Sturgeon Bay, Wis	2	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60–70	Mud	50	(1)	1
Port Washington, Wis.	3	Sept. 25, 1920	18 miles E. ½ S	2½	65–48	Clay	285	(1)	2
	4	May 26, 1922	24 miles E. by N	3½	60–80	Mud		(2)	5
Milwaukee, Wis	5	Mar. 24, 1919		2½	50			(2)	5
	6	Sept. 23, 1920	27 miles ESE	2½	60	Red clay	250	(1)	2
Wm. Lahmann [3]	7	December–January.	40 miles ESE		80–90				
C. Tamms	8	April–June	do	3½	80–90				
Racine, Wis., C. Hyttel, sr.	9	January	Off city	3½	60				
Michigan City, Ind	10	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30–40	Clay		(1)	1
	11	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Mud, clay	535	(1)	
Grand Haven, Mich	12	Mar. 20, 1919	12 miles west	2¾	50–55	Clay		(2)	5
Ludington, Mich	13	Aug. 30, 1920	17 miles W. ½ S	2¾	60–70	do		(2)	4
Manistee, Mich., Peter Petersen; Hans P. Petersen.	14	December–January.	5–8 miles west	4⅛	40–80	do			
Frankfort, Mich	15	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	(1)	1
Northport, Mich	16	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40–60	Mud	200	(1)	4
	17	July 31, 1923	do	2¾	40–60	do		(1)	13
Charlevoix, Mich	18	June 30, 1920	3 miles northwest	2¾	40–65	Clay		(2)	1
	19	Aug. 11, 1923	3 miles NW. ½ W	2¾	35–60	Red clay	375	(1)	3
Manistique, Mich	20	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70		200	(1)	1
Chicago, Ill. [4]									1

[1] Rare.
[2] Lift not examined or percentage not ascertained.
[3] See note, Table 20.
[4] Field Museum collection, borrowed specimens.

TABLE 41.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys nigripinnis from Lake Michigan, selected according to locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1564	Grand Haven, Mich.	272	18+31	♀	81	4.3	5.7	8.0	9.0	2.5	8.3	3.4	6.4	1.9	2.1	2.8	3.2
1684	Milwaukee, Wis.	274	18+32	Im. ♂	86	4.4	6.0	9.4	8.8	2.7	7.7	3.4	6.8	2.0	2.1	3.0	3.3
1686	do.	265	19+31	Im. ♀	81	4.4	6.3	9.8	9.2	2.9	7.6	3.8	6.4	1.6	2.1	3.0	3.3
2891	Charlevoix, Mich.	286	16+30	♀	77	4.1	5.6	9.1	8.6	2.8	8.1	3.5	7.1	2.0	2.0	2.7	3.2
3203	Washington Harbor, Wis.	262	16+30	♂	81	4.3	5.6	9.7	8.4	2.7	8.8	3.9	8.4	2.1	2.1	2.7	3.2
3305	Sturgeon Bay, Wis.	254	19+29	♂	78	4.1	5.4	8.7	8.7	2.7	7.6	4.1	7.9	1.9	2.0	2.7	3.1
3397	Ludington, Mich.	294	19+32	♂	85	4.2	6.0	9.7	8.8	2.9	7.3	4.2	8.9	2.0	2.0	2.8	3.2
3550	Michigan City, Ind.	259	18+34	Im. ♀	83	4.3	6.1	9.5	8.6	2.7	7.6	4.1	8.0	1.9	2.1	3.0	3.3
3684	Port Washington, Wis.	294	16+28	♀	82	4.4	6.2	8.9	9.2	2.7	7.7	3.8	7.7	2.0	2.1	3.0	3.3
3987	Frankfort, Mich.	300	17+30	♀	87	4.4	6.0	8.8	9.4	2.6	7.7	3.9	7.9	1.9	2.2	3.0	3.4

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
1564	Grand Haven, Mich.	4.3	4.3	2.7	3.8	2.0	3.9	5.1	3.2	2.0	2.9	1.8	1.3	11	12	12	17	1.3	1.0	8
1684	Milwaukee, Wis.	4.6	4.2	2.6	3.7	2.0	3.3	5.6	3.1	1.8	2.7	1.8	1.4	10	12	12	17	1.5	1.0	9
1686	do.	4.7	4.4	2.6	3.7	2.0	3.2	4.9	3.1	1.8	2.6	1.8	1.4	10	11	12	15	1.7	1.0	8
2891	Charlevoix, Mich.	4.3	4.4	2.7	3.7	2.0	3.4	6.8	3.2	2.0	2.7	1.7	1.4	10	12	11	18	1.6	.99	10
3203	Washington Harbor, Wis.	4.2	4.0	2.7	3.5	2.0	3.5	5.5	3.1	2.0	2.7	1.6	1.5	10	13	11	17	1.8	.94	8
3305	Sturgeon Bay, Wis.	4.2	4.2	2.6	3.6	2.0	3.3	5.0	3.1	2.0	2.8	1.6	1.3	11	12	12	18	1.5	1.0	8
3397	Ludington, Mich.	4.5	4.3	2.7	3.9	2.0	3.2	5.5	3.0	1.9	2.8	1.6	1.4	10	12	11	15	1.7	1.0	9
3550	Michigan City, Ind.	4.7	4.3	2.7	3.9	2.0	3.3	5.9	3.0	1.9	2.7	1.6	1.4	10	13	11	16	1.6	.93	9
3684	Port Washington, Wis.	4.7	4.4	2.6	4.1	1.9	2.9	5.4	3.1	1.8	2.9	1.8	1.3	10	12	11	17	1.5	1.0	9
3987	Frankfort, Mich.	4.6	4.4	2.6	3.7	2.0	3.3	6.0	3.2	1.9	2.7	1.7	1.5	10	11	12	17	1.5	.99	9

TABLE 42.—*Records of the occurrence of Leucichthys nigripinnis in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined, +200 mm.
Lake Huron proper:									
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef	2¾	35–50	Clay		(1)	1
Rogers, Mich.	2	July 24, 1917		2¾	60–70	do		(2)	3
Alpena, Mich.	3	Aug. 13, 1917	38 miles east of can buoy	2¾	70–80	do	1,470	(2)	10
	4	Sept. 7, 1917	Center of lake east of can buoy	2¾	70–80	do	3,250	45	3
	5	Sept. 10, 1917	Center of lake northeast of can buoy.	2¾	60–70	do	1,300	12	
	6	Sept. 12, 1917	Center of lake east of can buoy	2¾	65–80	do	2,610	30	
	7	Sept. 14, 1917	Center of lake northeast of can buoy.	2¾	65–80	do	1,200	10	1
	8	Sept. 17, 1917	do	2¾	60–70	do		18	
	9	Sept. 21, 1917	Center of lake east of can buoy	2¾	65–70	do		55	9
	10	Sept. 24, 1917	do	2¾	65–80	do		63	
	11	Sept. 26, 1917	do	2¾	65–80	do		30	
	12	Oct. 17, 1917	do	2¾	65–80	do		45	4
	13	Oct. 20, 1917	do	2¾	65–80	do		55	8
	14	Aug. 30, 1919	18 miles N. by E. ½ E. of Thunder Bay Island.	2¾	60–64	do		10	2
	15	Sept. 3, 1919	28 miles E. ¼ S. of can buoy	2¾	60–64	do		10	2
	16	Aug. 7, 1920	19 miles NE. ½ N. of Thunder Bay Island.	2¾	60–65	do	3,500	5	
	17	June 28, 1923	19 miles northeast of Thunder Bay Island.	2¾	60–70		2,100	75	

[1] Rare. [2] Lift not examined or percentage not ascertained.

TABLE 42.—*Records of the occurrence of Leucichthys nigripinnis in Lake Huron*—Continued

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage	Preserved specimens examined, +200 mm.
Lake Huron proper—Continued.									
Alpena, Mich.	18	June 30, 1923	17 miles NE. by N.¾N. of Thunder Bay Island.	2¾	65–70	Clay	1,600	24	7
	19	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60–70	do	2,000	82	3
	20	July 5, 1923	18 miles NE.¾E. of Thunder Bay Island.	2¾	80–100	do	6,000	90	7
	21	July 7, 1923	13 miles NE.½N. of Thunder Bay Island.	2¾	60	do	1,400	15	2
Harbor Beach, Mich.	22	Oct. 27, 1917	35 miles NE. by N.¾N. of city.	2¾	50	do	1,183	(1)	1
Georgian Bay:									
Lions Head, Ontario.	23	July 30, 1919	21 miles east of Surprise Shoal.	3	60	Mud	400	(1)	5
	24	Oct. 6, 1919	Off White Bluff	3	70	do	425	95	10
Wiarton, Ontario.	25	Nov. 6, 1917	6½ miles northeast of Griffith Island.	3	45–60	do		(2)	2
	26	July 28, 1919	Off Cape Croker	3	52	do	500	(1)	4
	27	June 10, 1922	do	3				(2)	47
	28	June 26, 1923	do	3				(2)	3

[1] Rare. [2] Lift not examined or percentage not ascertained.

TABLE 43.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys nigripinnis from Lake Huron, selected according to size*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
129	Alpena, Mich.	320	♀	16+28	78	4.3	6.0	9.3	9.3	2.9	8.0	3.5	7.2	2.0	2.1	2.9	3.4
130	do	340	♀	19+32	80	4.2	5.6	8.9	9.7	2.6	8.5	3.4	6.1	1.7	2.1	2.8	3.3
204	do	290	♂	18+33	77	4.1	5.6	8.0	8.3	2.7	8.2	4.1	8.0	1.9	2.0	2.8	3.1
205	do	312	♀	16+30	79	4.1	5.5	8.7	9.6	2.6	7.8	3.6	7.4	1.9	2.0	2.7	3.1
763	do	304	♂	16+31	82	3.9	5.5	8.7	9.3	2.8	8.3	3.8	8.0	2.1	1.8	2.6	3.0
770	do	297	♂	17+30	83	4.1	5.5	8.7	8.2	2.8	7.7	3.5	7.4	2.1	2.0	2.6	3.0
771	do	302	♀	17+30	78	4.0	5.5	7.7	7.3	2.5	7.7	3.6	7.4	2.0	1.9	2.7	2.9
772	do	303	♀	18+32	85	4.0	5.7	8.8	8.3	2.7	8.1	3.9	7.9	2.0	2.0	2.8	3.1
800	do	255	♀	18+32	77	4.0	5.6	8.9	9.1	2.9	9.0	4.2	7.8	1.8	2.0	2.7	3.1
965	do	314	♀	17+30	85	4.1	5.7	9.5	9.3	2.7	7.8	4.0	6.5	1.6	1.9	2.7	3.1

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
129	Alpena, Mich.	4.7	4.1	2.6	3.6	1.9	3.6	4.7	3.0	1.8	2.6	1.7	1.4	10	11	12	16	1.6	1.0	9
130	do	4.4	4.2	2.7	3.6	2.0	3.7	5.3	3.2	2.0	2.7	1.8	1.6	10	11	11	18	1.3	.97	10
204	do	4.3	4.0	2.5	3.7	1.9	3.6	4.6	3.0	1.9	2.7	1.6	1.3	11	13	12	16	1.4	.94	8
205	do	4.2	4.1	2.6	3.5	2.0	3.5	5.1	3.0	1.9	2.6	1.7	1.5	10	11	12	15	1.4	1.0	9
763	do	4.3	4.1	2.7	3.7	2.1	3.7	4.2	2.9	1.9	2.6	1.6	1.5	10	12	11	18	1.5	.98	9
770	do	4.1	3.9	2.5	3.5	1.9	3.2	4.5	2.9	1.8	2.6	1.6	1.0	11	12	11	17	1.5	.97	9
771	do	4.1	4.0	2.5	3.7	1.9	3.4	4.5	2.8	1.8	2.7	1.5	1.3	11	13	11	17	1.3	.84	10
772	do	4.3	4.2	2.6	3.8	2.0	3.2	4.2	3.0	1.9	2.7	1.7	1.3	11	11	12	17	1.4	.92	10
800	do	4.4	4.1	2.4	3.6	1.9	3.9	6.2	3.0	1.8	2.6	1.7	1.3	10	11	11	16	1.5	.92	9
965	do	4.3	4.1	2.6	3.8	2.0	3.6	4.8	3.0	1.9	2.8	1.7	1.3	10	11	12	17	1.6	1.0	8

TABLE 44.—*Records of the occurrence of Leucichthys nigripinnis cyanopterus in Lake Superior*

[For each record is given, if known, the date and locality, the kind and quantity of gear used to make it, the depth of the water and the character of bottom where made, the number of the fish gilled in the netting, the percentage of this species among them, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth in fathoms	Bottom	Length of net, in feet	Nights set	Number of fish gilled	Percentage of nigripinnis	Preserved specimens examined [1]
Sault Ste. Marie, Mich.	1	June 14, 1922	10 miles NW. by W. ¼ W. of Point Iroquois Light in Whitefish Bay.	2½, 2¾	38		1,800	2	200	1	2
Grand Marais, Mich.	2	Oct. 3, 1917		4½	+65						25
Chas. Macdonald,[2] Joseph Desjardins.	3	April – October, up to about 1907.		3¼	+65	Clay					
Marquette, Mich.	4	Aug. 5, 1921	31 miles N. ¾ E.	4½	100	Reddish-brown clay.					10
	5	Aug. 8, 1921	6 miles NE. ¾ N.	2½, 2¾	42–65	Red clay	2,500	5	250	3	7
	6	Aug. 11, 1921	18 miles NE. by N.	2½, 2¾	100–80		2,500	7	200	10	20
	7	1923									10
	8	November, 1925									2
W. J. Parker	9	April – August		3¼	60–100	Clay					
Ontonagon, Mich.	10	Aug. 16, 1921	54 miles W. by N.	4½	25–80						1
	11	Aug. 25, 1921	6 miles NNW.	2½, 2¾	20–38	Sand, clay	2,500	7	500	0.2	1
K. McLean	12	April–Nov. 1	Off city	3½	60–100	Clay					
Apostle Islands, Wis.	13	July 11, 1922	Between Cat and South Twin Islands.	2½, 2¾	15–20	Sand	2,200	1	300	.3	1
	14	July 14, 1922	25 miles north of South Twin Island.	4½	50–90	Red and yellow clay.					2
	15	July 15, 1922	20 miles northwest of Rocky Island.	4½	35–65	Clay					1
Duluth, Minn.	16	July 17, 1922	20 miles NE. by E.	2⅝	30–40	Sand					2
Grand Marais, Minn.	17	Sept. 14, 1921	Off Terrace Point	2½, 2¾	30–65	Clay	3,500	7	2,000	.15	3
	18	July 17, 1922	do	4½	30–65	do					1
James Scott	19	April – October, 1903–1906.	5–6 miles off the coast	3½	80–90	do					
Rossport, Ontario.	20	Oct. 4, 1921	Off Bread Rock	2½, 2¾	80–90	Grayish-brown clay.	1,000	4	210	10	23
Port Coldwell, Ontario.	21	Oct. 22, 1923		4½							5
Michipicoten Island, Ontario.	22	June 19, 1922	6 miles northeast of East-End Light.	4½	15–35						6
	23	June 22, 1922	3 miles SE. ½ S. of Quebec Harbor Light.	2½, 2¾	80	Blue clay	2,500	3	75	21	16
John McMillan. Luther McArthur.	24	1900–1903	Northwest and south of the island.	3½	60–110	Clay					
Coppermine Point, Ontario.	25	June 24, 1922	Agawa Bay	4½	40–50	Mud					1
	26	June 26, 1922	Off Alona Bay	2½, 2¾	60		1,800	5	200	13	27
Marquette, Mich.[3]											2

[1] All over 200 millimeters except 1 specimen 198 millimeters long under record 22.
[2] See note, Table 20.
[3] U. S. National Museum collection, borrowed specimens.

TABLE 45.—*Numerical expressions of certain systematic characters of the types of the cyanopterus and prognathus forms of Leucichthys nigripinnis from Lakes Superior and Ontario, respectively, and for nine other specimens of that species from Lake Superior, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
64672[1]	Marquette, Mich.	345	14+25	♀	77	4.0	5.6	8.9	9.6	2.8	7.5	3.8	8.0	2.0	1.9	2.7	3.1
866	Grand Marais, Mich.	284	14+24	♀	87	4.1	5.6	9.0	9.2	2.7	7.7	3.7	8.4	2.2	2.0	2.7	3.2
1293	do	289	16+26	♂	80	3.9	5.2	9.6	8.3	2.8	8.6	4.0	9.0	2.2	1.9	2.6	3.0
1295	do	292	16+28	♂	85	4.2	5.8	10.0	8.8	2.7	7.8	4.2	8.8	2.0	2.0	2.8	3.2
1296	do	298	14+24	♀	84	4.1	5.5	9.2	8.5	2.7	7.5	3.5	8.0	2.2	2.0	2.7	3.0
1322	do	330	15+25	♂	85	4.1	5.2	8.6	8.6	2.7	7.8	3.7	8.0	2.1	1.9	2.4	3.2
57001	Michipicoten Island, Ontario	272	14+26	♂	82	4.1	5.4	9.0	7.7	2.9	8.2	4.1	8.3	2.0	2.0	2.6	3.0
57028	do	287	15+24	♀	85	4.0	5.3	9.1	8.7	3.0	7.7	4.1	7.9	1.9	2.0	2.6	3.0
57146	Alona Bay	246	15+24	♀	88	4.0	5.4	9.6	8.7	2.8	8.2	3.8	7.6	2.0	2.0	2.6	3.0
57188	Apostle Islands, Wis.	267	15+25	♀	88	4.1	5.6	8.3	7.8	2.8	7.9	3.8	7.6	2.0	2.0	2.7	3.0
45568[1]	"Lake Ontario"	297	[2]14+28	Ev.	77	4.1	5.7	9.3	8.7	2.8	8.3	3.4	7.4	2.1	2.0	2.8	3.2

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
64672[1]	Marquette, Mich.	4.2	4.7	2.7	3.9	1.9	3.8	5.6	3.4	1.9	2.8	1.6	1.4	11	12	12	17	1.4	1.0	9
866	Grand Marais, Mich.	4.4	4.5	2.6	3.7	2.0	3.9	5.6	3.3	1.9	2.7	1.8	1.4	11	12	12	17	1.5	1.0	9
1293	do	4.0	4.3	2.6	3.6	2.0	4.1	4.2	3.2	2.0	2.7	1.5	1.3	10	11	11	18	1.5	.95	9
1295	do	4.0	4.4	2.5	3.7	2.0	3.3	5.6	3.2	1.9	2.7	1.7	1.3	10	13	11	17	1.7	.97	9
1296	do	4.1	4.7	2.6	3.6	2.0	4.2	5.6	3.5	2.0	2.7	1.6	1.3	10	12	12	17	1.5	.93	9
1322	do	4.0	4.4	2.5	3.6	1.9	3.6	5.2	3.5	2.0	2.8	1.9	1.3	11	14	11	17	1.3	.85	9
57001	Michipicoten Island, Ontario	3.9	4.4	2.7	3.8	2.0	3.8	5.4	3.3	2.0	2.9	1.7	1.3	10	13	12	17	1.4	.86	9
57028	do	4.0	4.4	2.7	3.7	2.0	3.6	5.8	3.3	2.0	2.8	1.6	1.4	10	12	12	18	1.4	.88	9
57146	Alona Bay	4.1	4.2	2.6	3.6	1.9	3.8	5.6	3.2	1.9	2.7	1.6	1.4	10	12	11	19	1.6	.93	9
57188	Apostle Islands, Wis.	4.3	4.4	2.6	3.7	2.0	3.5	6.4	3.2	1.9	2.7	1.6	1.3	11	12	11	17	1.5	.94	9
45568[1]	"Lake Ontario"	4.5	4.6	2.4	3.6	1.8	4.1	5.1	3.3	1.7	2.6	2.1	1.4	11	13	12	16			9

[1] Types, U. S. National Museum catalogue number.
[2] The count of 14 is not complete, because some of the rakers have been lost.

TABLE 46.—*Records of the occurrence of Leucichthys nigripinnis regalis in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill net mesh, in inches	Depth, in fathoms	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
1	July 26, 1921	Off Macdiarmid		15	2	
2	July 26, 1922	do	2½, 2¾	30	96	2
3	Sept. 8, 1923	do		6		1
4	Sept. 10, 1923	do			2	
5	Aug. 21, 1921	Off Blackwater River		50	2	
6	July 28, 1922	Off Livingston Point	2½, 2¾	56		
7	Sept. 6, 1923	Off Selwyn Island			1	
8	Sept. 3, 1923	Humboldt Bay			9	1
9	Sept. 5, 1923	Off McKellar Island			4	
10	Aug. 10, 1921	Off Murchison Island		15	5	
11	Aug. 15, 1922	do		25	17	
12	Aug. 21, 1923	Ombabika Bay		14	7	
13	June 19, 1924	do		10	5	
14	Aug. 17, 1922	Off Whitesand River		25	4	
15	June 21, 1924	Off Caribou Island		25	3	
16	Aug. 1, 1922	Grand Bay	4½	15-20	2	
17	Aug. 27, 1921	Off Gros Cap		20	1	
18	Sept. 3, 1923	do		10	1	
19	July 25, 1922	Off Source of Nipigon River	2½, 2¾	10-15	42	1
20	Aug. 28, 1923	Off Virgin Island		10-15	3	
21	Aug. 30, 1923	do		19	1	
22	July 23, 1924	Sandy Bay		10		1
23	Aug. 15, 1922	Unknown			10	
24	Oct. 26, 1922	do			5	
25	June 14, 1924	do	4½		2	

[1] All but records 2, 6, 16, 19, and 24 from University of Toronto collections.

TABLE 47.—*Numerical expressions of certain systematic characters for the type of the regalis form of Leucichthys nigripinnis from Lake Nipigon and for 11 cotypes, 10 over 200 mm. long and 2 under 200 mm. long, selected according to size*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
Over 200 mm.	57235	Nipigon River source.	236	16+31	Im. ♂	75	4.0	5.4	7.9	9.1	2.8	7.5	3.8	8.7	2.2	1.9	2.6
	57248	do	240	17+29	Im. ♂	74	4.0	5.4	8.0	8.2	2.8	8.5	3.8	8.2	2.1	2.0	2.7
	57319	do	294	18+33	♀	76	3.9	5.7	9.8	10.4	3.1	7.9	4.0	8.4	2.0	2.0	2.9
	57414	Macdiarmid, Ontario.	280	18+32	♂	71	4.1	5.4	8.6	9.4	2.7	8.0	4.0	9.0	2.2	2.0	2.7
	[1] 57416	do	326	18+30	♀	72	4.1	5.8	7.7	8.5	2.7	9.0	3.5	7.7	2.1	2.0	2.9
	57422	do	278	16+28	♀	74	3.9	5.4	8.6	9.5	2.6	8.1	3.8	8.1	2.1	1.9	2.7
	57431	do	326	19+32	♀	69	4.0	5.3	7.4	8.4	2.7	9.5	3.1	7.7	2.5	2.0	2.6
	57502	do	298	18+31	♀	71	4.1	5.9	8.0	9.0	2.6	8.2	3.8	8.0	2.1	2.0	2.9
	57516	do	249	18+31	Im. ♀	71	4.0	5.6	8.3	8.8	2.7	8.3	3.6	7.7	2.1	2.0	2.8
	57616	do	277	18+32	♀	79	4.0	5.6	8.9	9.6	2.8	8.9	3.9	8.1	2.0	2.0	2.7
Under 200 mm.	[2] N1025	Humboldt Bay.	174	17+31	Im. ♂	72	3.8	5.3	9.1	8.7	2.9	7.5	4.3	9.1	2.2	1.9	2.6
	[2] N1168	Sandy Bay	159	17+30	Im. ♀	76	3.7	5.1	8.8	7.9	2.8	8.8	4.6	8.8	1.8	1.8	2.5

Size	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 mm.	57235	3.0	4.2	3.8	2.5	3.8	1.9	3.0	5.4	2.8	1.8	2.7	1.4	1.5	11	12	12	16	1.6	1.0	9
	57248	3.1	4.2	3.9	2.6	3.7	1.9	3.2	4.9	2.8	1.9	2.7	1.3	1.4	12	13	12	16	1.6	1.0	8
	57319	3.1	4.5	4.1	2.6	4.0	2.0	3.2	5.2	2.8	1.8	2.7	1.6	1.5	9	11	11	16	1.6	1.1	9
	57414	3.2	4.3	3.7	2.5	3.6	1.8	3.2	4.8	2.8	1.9	2.7	1.5	1.4	11	11	11	16	1.6	1.0	9
	[1] 57416	3.2	4.5	4.1	2.6	3.9	1.9	3.4	4.3	2.9	1.8	2.7	1.6	1.4	10	12	12	16	1.4	1.0	8
	57422	3.1	4.2	3.8	2.5	3.6	1.8	3.5	5.0	2.8	1.8	2.6	1.6	1.3	10	12	12	16	1.5	1.2	9
	57431	3.2	4.2	4.0	2.7	3.8	1.9	3.2	5.0	3.0	2.1	2.9	1.6	1.6	11	12	11	16	1.4	1.1	9
	57502	3.2	4.6	4.0	2.5	4.0	2.0	3.4	5.1	2.7	1.7	2.7	1.6	1.4	10	11	12	16	1.5	1.1	8
	57516	3.1	4.3	4.0	2.6	3.9	1.9	3.6	4.9	2.8	1.8	2.7	1.4	1.3	11	12	11	16	1.6	1.0	9
	57616	3.2	4.4	3.9	2.7	4.0	2.0	3.6	5.3	2.8	1.9	2.8	1.6	1.5	10	11	12	17	1.5	1.0	8
Under 200 mm.	[2] N1025	2.9	4.0	3.7	2.6	4.0	2.0	3.6	5.0	2.7	1.8	2.9	1.4	1.3	10	12	12	17	-----	1.1	8
	[2] N1168	2.9	3.9	3.3	2.6	3.8	1.9	3.7	5.1	2.4	1.9	2.8	1.4	1.3	10	12	11	16	1.6	1.0	9

[1] Type, U. S. National Museum catalogue number 88354. [2] University of Toronto collection.

TABLE 48.—*Records of the occurrence of Leucichthys kiyi in Lake Michigan*

For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Ports from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Weight of lift, in pounds	Percentage of kiyi	Preserved specimens examined	
									+200 mm.	−200 mm.
Washington Harbor, Wis.	1	Aug. 18, 1920	14 miles E. ¾ N. of Rock Island.	2½	30–50	------	------	(1)	------	1
	2	Aug. 19, 1920	20 miles E. ½ N. of Rock Island.	2½, 2⅝	71–90	Clay-mud	900	65	9	12
Sturgeon Bay, Wis.	3	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60–70	Mud	50	65	9	11
Algoma, Wis.	4	Aug. 24, 1920	10 miles E. by N.	2½	35–50	Gravel-mud	310	(2)	4	2
Sheboygan, Wis.	5	Oct. 1, 1920	11 miles southeast	2½	60	Clay	200	(1)	11	1
Port Washington, Wis.	6	Sept. 25, 1920	18 miles E. ½ S.	2½	65–48	do	285	35	7	1
	7	May 26, 1922	8 miles northeast	2½	20–35	Mud	------	(1)	------	1
Milwaukee, Wis.	8	Sept. 23, 1920	27 miles ESE	2½	60	Red clay	250	60	5	------
Michigan City, Ind.	9	Sept. 3, 1920	22 miles NW. by N. ½ N.	2½	30–40	Clay	------	6	4	------
	10	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Mud, clay	535	(2)	2	------
	11	Nov. 8, 1920	18 miles NNW	2½	30–38	Clay	1,000	(2)	------	------
	12	Nov. 19, 1920	30 miles NNW	4½	48–50	do	------	(2)	1	------
Grand Haven, Mich.	13	Mar. 20, 1919	12 miles west	2¾	50–55	do	------	(1)	11	1
Ludington, Mich.	14	Aug. 30, 1920	17 miles W. ½ S.	2¾	60–70	do	------	(1)	13	------
	15	do	12 miles W. ½ S.	2¾	45–50	do	------	(1)	10	------
Manistee, Mich.	16	Aug. 28, 1920	9 miles northwest	4½	28–32	------	------	(2)	------	1
Frankfort, Mich.	17	Oct. 4, 1920	9 miles north of Point Betsie.	2¾	60–70	Blue clay	1,400	38	5	2
Northport, Mich.	18	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40–60	Mud	------	9	32	4
Charlevoix, Mich.	19	June 29, 1920	5 miles N. by E.	2¾	40–55	Clay, mud	------	(2)	1	1
	20	June 30, 1920	3 miles northwest	2¾	40–65	Clay	------	(1)	------	4
	21	Aug. 11, 1923	3 miles NW. ½ W.	2¾	35–60	do	375	(2)	7	------
Manistique, Mich.	22	Aug. 12, 1920	15 miles SE. by S. ½ S.	2¾	60–70	------	200	(2)	------	1

[1] Lift not examined or percentage not ascertained. [2] Rare.

TABLE 49.—*Numerical expressions of certain systematic characters for the type and for nine cotypes of Leucichthys kiyi from Lake Michigan, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
84100[1]	Sturgeon Bay, Wis.	191	15+25	♀	85	4.0	5.4	9.1	9.9	2.9	8.1	4.0	7.3	1.8	2.0	2.5	3.1
2858	Charlevoix, Mich.	227	15+25	♀	82	3.9	5.3	9.8	8.3	3.0	8.7	3.9	8.4	2.1	2.0	2.5	2.9
3276	Sturgeon Bay, Wis.	169	14+26	♂	80	3.9	5.2	8.9	8.4	2.8	7.6	4.1	9.9	2.4	2.0	2.7	2.9
3295	Washington Harbor, Wis.	179	15+23	♀	77	3.9	5.4	9.9	10.0	3.1	8.4	4.4	9.9	2.2	2.0	2.7	2.9
3370	Algoma, Wis.	199	14+24	♀	83	4.1	5.5	9.0	9.8	2.8	7.7	3.9	8.2	2.1	2.1	2.8	3.1
3483	Ludington, Mich.	222	14+23	♀	86	4.1	5.5	9.0	8.4	3.0	7.9	3.5	8.2	2.2	2.1	2.9	3.2
3597	Milwaukee, Wis.	219	14+25	♀	84	4.1	5.7	9.8	10.0	2.7	8.1	3.5	8.4	2.3	2.1	3.0	3.1
3898	Sheboygan, Wis.	201	13+25	♀	79	3.9	5.4	9.1	9.1	2.9	8.5	3.9	8.0	2.0	2.0	2.7	3.0
3972	Frankfort, Mich.	204	14+23	♀	82	3.7	5.1	8.9	9.7	2.8	8.8	3.8	8.1	2.1	2.0	2.7	2.8
4008	Michigan City, Ind.	210	14+24	♂	80	4.0	5.7	9.3	9.1	2.8	8.3	4.0	9.3	2.3	2.0	3.0	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
84100[1]	Sturgeon Bay, Wis.	4.2	3.9	2.7	3.6	1.9	3.6	6.5	2.9	2.0	2.7	1.6	1.2	10	11	11	15	1.5	-----	9
2858	Charlevoix, Mich.	4.0	4.1	2.5	3.4	1.8	3.8	8.0	3.0	1.8	2.5	1.5	1.1	10	13	12	17	1.7	1.0	9
3276	Sturgeon Bay, Wis.	3.9	3.8	2.3	3.5	1.9	3.5	7.1	2.8	1.7	2.6	1.4	1.1	10	11	12	16	1.7	1.0	9
3295	Washington Harbor, Wis.	4.0	3.8	2.6	3.6	1.9	3.6	6.2	2.7	1.9	2.7	1.5	1.1	10	11	11	16	1.8	1.1	9
3370	Algoma, Wis.	4.1	3.9	2.4	3.6	1.9	3.0	7.0	2.9	1.8	2.7	1.4	1.2	10	10	11	16	1.6	1.1	9
3483	Ludington, Mich.	4.3	3.8	2.4	3.5	1.9	3.1	6.0	2.8	1.8	2.6	1.5	1.1	10	12	12	16	1.8	1.0	8
3597	Milwaukee, Wis.	4.3	4.3	2.6	3.5	1.9	3.1	7.9	3.1	1.9	2.5	1.6	1.1	10	10	11	18	1.7	1.2	9
3898	Sheboygan, Wis.	4.2	4.0	2.5	3.6	1.9	3.9	6.0	2.9	1.8	2.6	1.3	1.1	10	11	12	17	1.8	1.2	9
3972	Frankfort, Mich.	3.8	4.0	2.5	3.8	2.0	3.9	7.2	2.9	1.9	2.8	1.4	1.0	10	11	12	16	1.7	1.1	9
4008	Michigan City, Ind.	4.3	4.3	2.6	3.7	2.1	3.2	6.7	2.9	1.8	2.6	1.5	1.0	10	11	11	17	1.8	1.2	9

[1] Type, U. S. National Museum number.

TABLE 50.—*Records of the occurrence of Leucichthys kiyi in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined	
								+200 mm.	−200 mm.
Lake Huron proper:									
Alpena, Mich.	1	Sept. 7, 1917	Center of lake east of can buoy.	2¾	70–80	Clay	Only specimen taken in lift.	-----	1
	2	Sept. 12, 1917	do	2¾	65–80	do	do	-----	3
	3	Sept. 14, 1917	Center of lake northeast of can buoy.	2¾	65–80	do	do	1	8
	4	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60	do	do	-----	18
	5	Sept. 19, 1917	Center of lake northeast of can buoy.	-----	65–80	do	do	2	3
	6	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65	do	do	-----	16
	7	Sept. 21, 1917	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–75	do	do	-----	36
	8	do	Center of lake east of can buoy.	2¾	65–70	do	do	-----	8
	9	Oct. 17, 1917	do	2¾	65–80	do	do	2	-----
	10	Oct. 20, 1917	do	2¾	65–80	do	do	2	1
	11	Sept. 13, 1919	Off Presque Isle Light	1½	60	do	Rare	-----	8

TABLE 50.—*Records of the occurrence of Leucichthys kiyi in Lake Huron*—Continued

Ports from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined +200 mm.	Preserved specimens examined −200 mm.
Lake Huron proper—Continued.									
Alpena, Mich.	12	Sept. 18, 1919	14 miles N. by E. of Thunder Bay Island.	2¾	65	----------	Only specimens taken in lift.	------	5
	13	do.		2¾			do.	------	18
	14	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–70	Clay	do.	3	32
	15	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60–70	do.	do.	1	6
	16	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80–100	do.	do.	5	29
	17	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60	do.	do.	------	4
Georgian Bay:									
Lions Head, Ontario.	18	July 30, 1919	21 miles east of Surprise Shoal.	3	60	----------	do.	------	2
	19	Oct. 6, 1919	Off White Bluff	3	70	Mud	do.	------	2
Wiarton, Ontario.	20	July 30, 1919	----------	3	--------	----------	do.	------	1

TABLE 51.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys kiyi from Lake Huron, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
27B	Alpena, Mich.	156	14+24	♀	83	3.7	4.9	11.1	8.2	3.2	8.2	5.3	11.1	2.0	1.9	2.6	2.8
382	do.	180	14+23	♀	77	3.9	5.1	8.8	7.7	3.1	8.5	3.6	7.5	2.1	2.0	2.6	2.9
560	do.	170	14+25	♀	80	3.8	5.1	10.3	8.5	3.1	8.0	4.3	8.9	2.0	1.9	2.6	2.9
581	do.	155	14+23	♀	87	3.8	5.3	10.3	9.6	3.1	8.3	5.0	8.8	1.7	2.0	2.7	2.9
559	do.	210	14+28	♀	83	3.9	5.0	9.2	8.1	2.6	7.5	3.5	7.5	2.1	1.9	2.4	2.9
775	do.	194	14+24	♀	86	3.8	5.1	8.8	8.0	2.8	8.0	3.5	8.8	2.4	2.0	2.6	2.9
949	do.	219	15+26	♀	89	3.9	4.9	8.7	8.7	2.7	7.8	3.9	8.7	2.2	1.8	2.5	3.0
958	do.	208	13+23	♀	79	3.7	4.9	8.8	9.0	2.8	8.3	3.8	8.3	2.1	1.8	2.4	2.9
976	do.	215	13+23	♀	81	3.8	5.2	8.9	8.9	2.9	8.2	3.7	8.6	2.3	1.9	2.6	3.0
54873	do.	238	16+27	♀	80	3.9	5.1	8.2	8.8	2.6	7.2	3.9	8.8	2.2	1.9	2.5	2.9

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
27B	Alpena, Mich.	3.7	4.0	2.6	3.4	1.9	4.0	6.4	3.0	1.9	2.5	1.9	1.0	10	12	11	15	2.0	1.0	9
382	do.	3.9	3.8	2.5	3.5	1.8	3.6	9.0	2.9	1.9	2.6	1.7	1.3	10	12	11	16	1.4	.89	9
560	do.	3.9	3.8	2.5	3.6	1.8	3.6	6.2	2.8	1.9	2.7	1.6	1.2	9	10	11	16	1.8	1.3	9
581	do.	3.1	3.8	2.6	3.6	1.9	4.0	7.6	2.7	1.9	2.6	1.4	1.2	9	11	11	15	1.8	1.1	9
559	do.	3.6	3.7	2.5	3.7	1.7	3.7	5.1	2.9	1.9	2.9	1.1	1.0	10	12	11	18	1.7	1.0	9
775	do.	3.9	4.0	2.4	3.5	-----	3.3	6.9	3.0	1.8	2.7	1.6	1.1	10	12	12	18	1.7	1.1	9
949	do.	4.2	4.0	2.6	3.6	1.9	3.4	5.0	2.9	1.9	2.6	1.7	1.1	10	11	11	16	1.7	1.0	8
958	do.	3.8	4.0	2.7	3.3	1.8	3.6	8.8	3.1	2.0	2.5	1.4	1.0	10	11	12	17	1.7	1.2	9
976	do.	4.1	4.1	2.4	3.4	1.9	3.9	6.7	3.0	1.7	2.5	1.5	1.2	10	10	11	16	1.7	1.1	9
54873	do.	3.8	4.3	2.6	3.5	1.9	3.3	7.4	3.2	1.9	2.7	1.3	1.0	10	12	11	16	1.5	1.1	10

TABLE 52.—*Records of the occurrence of Leucichthys kiyi in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, the abundance of this species in the lift, and the number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Grand Marais, Mich.	1	Oct. 3, 1917		4½	+65				6
Marquette, Mich.	2	Aug. 5, 1921	31 miles N. ¾ E.	4½	100	Reddish-brown clay.	Only specimens taken in lift.		11
	3	Aug. 8, 1921	6 miles NE. ¾ N.	1½	42–65	Red clay	do		2
	4	Aug. 11, 1921	18 miles NE. by N.	4½	100–80		do		2
	5	Nov. 22, 1922	Off Granite Island	4½				1	12
	6	Dec. 5, 1922	do	4½					39
	7	1923							1
	8	Nov. —, 1925							1
Apostle Islands, Wis.	9	July 14, 1922	25 miles north of South Twin Island.	4½	50–90	Red and yellow clay.	Only specimens taken in lift.		4
	10	July 15, 1922	14–18 miles NW. by N. of South Twin Island.	4½	40–90	Clay	do		1
Coppermine Point, Ontario.	11	June 24, 1922	Agawa Bay	4½	40–50	Mud	do	1	

TABLE 53.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys kiyi from Lake Superior, selected at random*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1298	Grand Marais, Mich.	174	♀	16+26	81	3.7	4.9	8.7	8.0	2.9	8.4	3.7	8.7	2.3	1.8	2.5	2.7
1357	do	171	♀	15+27	85	3.8	5.2	9.6	7.7	2.8	9.3	3.9	10.5	2.5	1.9	2.7	2.8
53548	Marquette, Mich.	169	♀	15+25	84	3.7	4.8	8.4	8.1	2.8	9.3	4.0	8.8	2.2	1.9	2.5	2.8
54232	do	182	♀	14+26	80	3.7	5.1	9.4	8.0	2.9	8.2	4.0	8.0	2.0	1.9	2.7	2.8
54242	do	155	♀	14+26	77	3.6	5.1	10.1	8.6	2.9	7.7	3.8	8.6	2.2	1.9	2.7	2.7
59066	do	203	♀	14+24	84	3.8	5.2	9.2	8.5	2.9	8.7	3.9	8.1	2.0	1.9	2.6	2.8
59070	do	195	♂	16+29	80	4.0	5.5	8.4	8.2	2.7	7.5	4.8	9.7	2.2	1.9	2.7	2.9
59085	do	178	♀	15+24	72	3.7	5.0	8.4	7.1	2.9	8.0	4.2	8.9	2.1	1.9	2.5	2.8
59088	do	183	♀	16+26	75	3.7	5.1	9.5	7.8	2.9	9.5	4.1	8.3	2.0	1.8	2.6	2.8
59100	do	191	♀	15+22	81	4.0	5.4	10.9	9.1	3.0	7.9	3.8	7.6	2.0	2.0	2.7	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
1298	Grand Marais, Mich.	3.7	3.6	2.6	3.8	1.8	3.5	5.5	2.7	1.9	2.8	1.2	1.0	10	12	11	17	1.7	1.0	9
1357	do	3.9	3.6	2.4	3.9	1.7	3.6	6.2	2.6	1.7	2.8	1.3	1.1	11	13	12	16	1.8	.94	8
53548	Marquette, Mich.	3.7	3.6	2.5	3.4	1.8	4.0	6.2	2.8	1.9	2.6	1.4	1.1	10	12	12	16	1.6	1.0	8
54232	do	3.9	3.8	2.5	3.8	1.9	3.5	5.5	2.7	1.8	2.7	1.2	1.1	9	11	11	16	1.9	1.0	9
54242	do	3.8	3.7	2.6	4.1	2.0	3.7	6.0	2.6	1.8	2.9	1.4	1.0	10	12	11	16	1.9	1.0	8
59066	do	3.9	3.8	2.6	3.9		3.8	6.4	2.8	1.9	2.8	1.4	1.0	11	11	11	17	1.8	1.0	8
59070	do	4.0	3.9	2.5	3.6	1.8	3.3	5.4	2.8	1.8	2.6	1.5	1.1	10	12	12	16	1.5	.93	8
59085	do	3.8	3.6	2.3	3.6	1.8	3.4	6.0	2.6	1.7	2.6	1.2	1.0	10	12	11	16	1.6	.91	9
59088	do	3.9	3.5	2.3	3.7	1.8	3.5	5.5	2.5	1.6	2.7	1.4	1.1	9	12	11	17	1.8	1.0	9
59100	do	4.0	3.7	2.4	3.6	1.8	3.0	5.9	2.8	1.8	2.6	1.5	1.1	9	11	11	16	1.8	1.0	9

TABLE 54.—*Records of the occurrence of Leucichthys kiyi in Lake Ontario*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the abundance of this species in the lift, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Percentage	Preserved specimens examined +200 mm.	Preserved specimens examined −200 mm.
Bronte, Ontario	1	June 29, 1921	13 miles E. ½ S.	2½, 2¾	40–50	Mud	(1)	7	
Brighton, Ontario	2	June 10, 1921	20 miles S. by W. of Presque Isle Light.	2½	40–50	do	(1)	1	
Sandy Pond, N. Y.	3	Aug. 30, 1923	14 miles west	1½, 2½, 3, 3¼, 3½	60	Clay and mud	(1)	1	
Selkirk, N. Y.	4	July 11, 1921	5 miles NNW. of Nine-Mile Point.	3	25–35	Blue clay	(1)	2	
Oswego, N. Y.	5	Sept. 1, 1923	Off Nine-Mile Point	3	30	Clay	(1)	1	
	6	Sept. 4, 1923	8½ miles W. by N. ½ N.	1½, 2½, 3	70–75	Clay and mud	(1)	8	3
Sodus Point, N. Y.	7	July 12, 1921	8½ miles NNW.	2½, 2¾	60	Mud and clay	25	26	1
Charlotte, N. Y.	8	July 4, 1921	7 miles off Braddock Point Light.	2½, 2¾	65	Blue and brown clay.	33	31	
Wilson, N. Y.	9	June 23, 1921	3 miles north	2½, 2¾	30	Brown clay	(1)	2	
	10	June 25, 1921	5 miles north	2½, 2¾	50	Clay and mud	40	15	1
	11	July 16, 1921	do	2½, 2¾	50	do	10		
	12	July 19, 1921	6½ miles N. by W. ½ by W.	2½, 2¾	65	Blue and brown clay.	75	31	2
	13	July 21, 1921	2 miles north	2½	20		(1)	3	

[1] Rare.

TABLE 55.—*Numerical expressions of certain systematic characters for the type of the orientalis form of Leucichthys kiyi and for nine cotypes from Lake Ontario, selected according to size and locality*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53221	Wilson, N. Y.	227	♀	17+28	82	4.2	5.6	9.9	10.8	2.6	8.3	3.1	7.8	2.4	2.1	2.9	3.2
53340	Charlotte, N. Y.	223	♂	16+29	81	4.1	5.7	9.6	10.2	2.6	7.8	4.0	7.9	1.9	2.1	2.9	3.1
54057	Wilson, N. Y.	224	♂	17+27	80	4.0	5.6	8.9	9.5	2.6	8.0	3.7	8.0	2.1	2.0	2.7	3.1
54064[1]	do	224	♂	15+28	79	4.0	5.4	9.0	9.2	2.8	8.8	3.6	7.4	2.0	2.0	2.7	3.2
54070	do	243	♀	17+29	78	4.2	5.8	8.3	8.9	2.8	9.0	3.6	7.8	2.1	2.1	2.9	3.3
54143	Sodus Point, N. Y.	202	♂	16+28	83	4.3	5.7	8.7	8.7	2.8	8.6	3.8	7.7	2.0	2.1	2.8	3.4
59815	Oswego, N. Y.	203	♂	16+28	81	3.9	5.2	9.7	10.0	2.9	7.8	3.7	9.2	2.4	2.0	2.8	3.0
54066	Wilson, N. Y.	199	♂	16+27	80	4.2	5.8	9.5	9.9	2.7	8.6	3.9	8.2	2.1	2.1	2.9	3.3
54206	Sodus Point, N. Y.	196	♂	16+29	81	4.0	5.6	9.0	9.8	2.8	7.8	3.9	7.8	2.0	2.1	2.9	3.1
59818	Oswego, N. Y.	199	♂	16+29	80	4.0	5.6	10.2	9.8	3.1	7.8	3.9	8.2	2.1	2.0	2.8	3.1

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53221	Wilson, N. Y.	4.3	4.1	2.5	3.6	2.0	3.0	5.6	3.0	1.9	2.7	2.0	1.3	9	9	10	15	1.6	1.1	8
53340	Charlotte, N. Y.	4.3	4.1	2.4	3.5	1.9	3.5	5.0	3.0	1.8	2.6	1.9	1.3	10	11	11	16	1.5	1.1	9
54057	Wilson, N. Y.	4.3	4.2	2.5	3.7	2.0	3.4	5.5	3.0	1.7	2.7	1.8	1.2	10	12	12	15	1.5	1.0	8
54064[1]	do	4.3	3.9	2.5	3.6	1.8	3.1	5.4	2.9	1.8	2.6	1.8	1.3	10	11	11	17	1.5	1.1	8
54070	do	4.6	4.1	2.6	3.7	1.9	3.4	4.7	2.9	1.9	2.7	2.0	1.5	10	11	11	15	1.3	1.0	9
54143	Sodus Point, N. Y.	4.5	4.0	2.5	3.4	1.9	3.7	5.1	3.0	1.9	2.6	2.1	1.3	10	10	11	16	1.6	1.0	9
59815	Oswego, N. Y.	4.1	4.2	2.7	3.7	1.8	3.1	4.8	3.1	2.0	2.7	1.6	1.2	9	10	12	17	1.7	1.1	8
54066	Wilson, N. Y.	4.6	3.9	2.5	3.5	1.9	3.0	4.6	2.8	1.8	2.5	1.9	1.3	9	12	11	16	1.6	1.1	9
54206	Sodus Point, N. Y.	4.2	3.8	2.5	3.7	1.9	3.7	5.4	2.8	1.8	2.7	1.7	1.2	10	10	11	16	1.4	1.1	9
59818	Oswego, N. Y.	4.4	4.1	2.4	3.5	1.9	3.2	4.8	2.9	1.7	2.5	1.8	1.2	9	10	11	15	1.6	1.0	9

[1] Type, U. S. National Museum No. 88352.

TABLE 56.—*Records of the occurrence of Leucichthys hoyi in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Weight of lift in pounds	Percentage of gilled fish	Preserved specimens examined	
								+200 mm.	−200 mm.
Washington Harbor, Wis.	1	Aug. 18, 1920	4 miles west of Boyer Bluff	2⅜	18–24		50	2	20
	2	do	5 miles west of Boyer Bluff	4	20		(1)	1	9
	3	do	14 miles E. ¾ N. of Rock Island	2½	30–50		(2)	1	64
	4	Aug. 19, 1920	3 miles WNW. of Boyer Bluff	4	20–40		(1)		1
	5	do	20 miles E. ½ N. of Rock Island	2½, 2⅝	71–90	900	(3)		5
Sturgeon Bay, Wis	6	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60–70	50	(3)		19
Algoma, Wis	7	Aug. 24, 1920	10 miles E. by N	2½	35–50	310	68	5	19
Sheboygan, Wis	8	Sept. 28, 1920	40 miles SE. by E	3½	35–40			2	28
	9	do	5 miles SE. by E	1½	30–32		75	4	81
	10	Oct. 1, 1920	11 miles southeast	2½	60	200	(2)	1	4
Port Washington, Wis	11	Sept. 25, 1920	18 miles E. ½ S	2½	65–48	285	53	4	34
	12	do	5 miles E. ½ S	1½	30		90		9
	13	Sept. 27, 1920	Off city	(4)	5		(5)		9
	14	May 26, 1922	8 miles northeast	2½	20–35		(2)		1
Milwaukee, Wis	15	Mar. 24, 1919		2½	50		(2)	15	54
	16	Sept. 23, 1920	27 miles ESE	2½	60	250	(5)	2	20
	17	Sept. 24, 1920	9 miles NNE	2½	22–25		(2)	3	20
	18	Nov. 15, 1920	20 miles ESE	2½	28–35		(6)		12
Racine, Wis	19	Oct. 8, 1920		1½	30		(2)		
Michigan City, Ind	20	Sept. 3, 1920	22 miles NW. by N. ½ N	2½	30–40		42	2	22
	21	Oct. 11, 1920	20 miles N. by W. ¾ W	2½	30–40	535	34		13
	22	Nov. 8, 1920	18 miles NNW	2½	30–38	1,000	10		12
	23	Nov. 19, 1920	30 miles NNW	4½	48–50		(1)	2	23
	24	do	17 miles NNW	2½	28–32	700	50	3	23
	25	do	10 miles NNW	2½	18		(3)		
	26	do	17½ miles NW. by N. ¾ N	2½	32		15		
	27	Mar. 2, 1921	14 miles NNW	1½	26		96		12
	28	do	21 miles NNW	2½	30	1,000	81		
	29	Mar. 4, 1921	15 miles NW. by N. ½ N	2½	28	1,000	96	10	2
	30	Apr. 1, 1921		2½	30		(2)		2
Grand Haven, Mich	31	Mar. 20, 1919	12 miles west	2¾	50–55		(2)	20	141
Ludington, Mich	32	Aug. 30, 1920	17 miles W. ½ S	2¾	60–70		(2)		1
	33	do	7 miles NW. by N	4½	14–26			1	49
	34	do	12 miles W. ½ S	2¾	45–50		(2)		5
Manistee, Mich	35	Aug. 27, 1920	4 miles west	1½	28–35		(2)		2
	36	Aug. 28, 1920	9 miles northwest	4½	28–32		(1)	3	7
Frankfort, Mich	37	Oct. 4, 1920	9 miles north of Point Betsie	2¾	60–70	1,400	22	4	33
Platte Bay, Mich. (field station).	38	July 21, 1923	1½ miles south of Otter Creek	1½	8–12		(1)		2
	39	July 23, 1923	do	1½	15–25		(1)	1	5
Northport, Mich	40	June 22, 1920	5 miles northwest of Cathead Light	2¾	40–60		(5)		2
	41	June 23, 1920	Off Northport Point	1½	28–40		60	1	67
	42	July 31, 1923	5 miles northwest of Cathead Light	2¾	40–60		(5)	33	10
Traverse City, Mich	43	July 18, 1923	West Bay	1½	30–40		50		
	44	July 25, 1923	Off Lees Point	1½	6–16		(1)		3
	45	July 26, 1923	1¼ miles south of Barrow Harbor	(4)	5				10
Charlevoix, Mich	46	June 29, 1920	5 miles N. by E	2¾	40–55		9	10	36
	47	June 30, 1920	3 miles northwest	2¾	40–65		(2)	4	28
	48	Aug. 10, 1923	8 miles NNW. of Big Rock Point	2¾	45–50	480	(5)		
	49	Aug. 11, 1923	3 miles NW. ½ W	2¾	35–60		(5)	1	
	50	Aug. 21, 1923		2¾		100	(3)	1	
Manistique, Mich	51	Aug. 11, 1920	13 miles SE. ½ E	4½	20		(1)		35
	52	Aug. 12, 1920	15 miles SE. by S. ½ S	2¾	60–70	200	(3)		15
Menominee, Mich	53	Aug. 16, 1920	8 miles south of Green Island	2⅜	16		(3)	1	33
Jackson Park Lagoon, Chicago, Ill.[7]									16
Pine, Ind.[7]									16
Ludington, Mich.[8]									13

[1] Only specimens taken.
[2] Lift not examined or percentage not ascertained.
[3] Rare.
[4] Pound net.
[5] Occasional.
[6] None.
[7] Field Museum collection, borrowed specimens.
[8] University of Michigan collection, borrowed specimens.

TABLE 57.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys hoyi from Lake Michigan selected at random*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1665	Milwaukee, Wis.	201	16+28	♀	75	4.3	5.9	10.4	11.0	2.9	7.7	4.1	8.2	2.0	2.1	2.9	3.5
1671	do.	220	16+27	♀	73	4.5	6.2	8.8	9.7	2.6	8.4	3.6	7.8	2.1	2.1	3.0	3.5
1704	do.	209	15+27	♂	69	4.3	5.8	11.4	10.3	2.7	8.7	3.8	7.4	1.9	2.2	3.0	3.4
3020	Menominee, Mich.	160	17+27	♀	69	4.1	5.7	8.8	9.6	2.7	7.4	4.0	8.4	2.1	2.0	2.8	3.2
3062	Washington Harbor, Wis.	208	15+28	♂	75	4.2	5.7	9.3	10.9	2.6	8.1	4.0	8.3	2.0	2.1	2.8	3.3
4027	Michigan City, Ind.	148	15+30	♀	74	4.0	5.2	9.5	9.7	2.7	8.7	4.2	8.9	2.1	2.0	2.6	3.1
4256	Milwaukee, Wis.	141	17+28	♀	74	4.0	5.5	9.7	9.9	2.9	8.0	4.8	8.4	1.9	2.0	2.7	3.1
4259	do.	171	15+26	♀	70	4.0	5.1	10.5	9.9	2.8	7.9	4.5	9.0	2.0	2.0	2.5	3.1
4344	Michigan City, Ind.	171	16+26	♀	67	4.1	5.6	10.1	10.0	2.8	8.5	4.0	8.5	2.1	2.1	2.8	3.2
4357	do.	201	17+29	♀	69	4.2	5.9	10.3	9.9	2.7	8.3	3.7	6.5	1.7	2.1	3.0	3.3

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
1665	Milwaukee, Wis.	4.7	4.1	2.7	3.8	2.0	3.0	5.4	3.0	2.0	2.8	2.2	1.6	9	10	11	15	1.6	1.2	9
1671	do.	4.9	4.0	2.5	3.9	2.0	3.2	6.4	2.9	1.8	2.8	2.2	1.5	10	11	11	16	1.4	1.0	8
1704	do.	4.6	3.9	2.5	3.6	1.7	3.7	5.3	2.9	1.8	2.6	2.0	1.6	7	11	11	15	1.8	1.1	8
3020	Menominee, Mich	4.5	3.9	2.6	3.9	1.9	3.3	5.5	2.8	1.9	2.8	1.8	1.3	10	13	11	15	1.7	1.2	8
3062	Washington Harbor, Wis.	4.5	4.0	2.6	3.7	2.0	3.4	5.1	3.0	1.9	2.7	1.8	1.5	9	10	11	16	1.8	1.3	8
4027	Michigan City, Ind.	4.1	3.7	2.6	4.0	2.0	3.8	5.2	2.8	1.9	3.0	2.0	1.4	9	11	11	16	1.6	1.0	8
4256	Milwaukee, Wis.	4.3	3.5	2.6	3.9	2.0	3.8	5.0	2.5	1.9	2.8	1.9	1.2	10	13	10	15	1.7	1.1	8
4259	do.	3.9	3.7	2.8	3.8	2.0	4.0	5.8	2.9	2.2	3.1	1.7	1.4	9	11	10	16	1.9	1.1	8
4344	Michigan City, Ind.	4.3	3.7	2.4	3.7	1.9	3.7	4.8	2.7	1.8	2.7	1.9	1.3	9	10	11	16	1.7	1.2	8
4357	do.	4.6	3.8	2.6	3.8	1.9	3.3	5.2	2.7	1.8	2.7	1.7	1.4	9	11	11	15	1.9	1.1	9

TABLE 58.—*Records of the occurrence of Leucichthys hoyi in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the weight of the lift and the abundance of this species in it, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined	
								+200 mm.	−200 mm.
Lake Huron proper:									
Cheboygan, Mich.	1	July 21, 1917	5 miles north of Spectacle Reef.	2¾	35–50	Clay	Occasional		16
	2	Sept. 29, 1917	2 miles northeast of Spectacle Reef.	2¾	35–50	do.	do.		9
	3	Oct. 1, 1917		2¾	35–50		Only specimens taken in lift.		11
	4	Oct. 15, 1919		1½	35		Abundant		44
Rogers, Mich.	5	Oct. 14, 1917	12 miles E. by N. ½ N. of city.	2¾	35	Clay	Common		31
Alpena, Mich.	6	Aug. 13, 1917	38 miles east of can buoy.	2¾	70–80		Only specimens taken in lift.		10
	7	Sept. 7, 1917	26 miles SE. by E. ¼ E. of can buoy.	4½	16–20		do.		19
	8	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30		Abundant		23
	9	Sept. 12, 1917	11 miles SE. ¾ E. of can buoy.	4½	15–17		Only specimens taken in lift.		4
	10	do.	Center of lake east of can buoy.	2¾	65–80		do.		14
	11	Sept. 14, 1917	Center of lake northeast of can buoy.	2¾	65–80		do.		23
	12	do.	24 miles SE. by E. ½ E. of can buoy.	4½	24		do.	1	51
	13	Sept. 17, 1917	13½ miles SE. by S. of can buoy.	4½	15		do.		2

TABLE 58.—*Records of the occurrence of Leucichthys hoyi in Lake Huron*—Continued

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Lake Huron proper—Continued.									
Alpena, Mich.	14	Sept. 18, 1917	17½ miles N. by E. of Thunder Bay Island.	2¾	60		Only specimens taken in lift.		34
	15	Sept. 19, 1917	Center of lake northeast of can buoy.	2¾	65–80		do		6
	16	Sept. 20, 1917	14 miles NE. by E. of Thunder Bay Island.	2¾	65		do		33
	17	Sept. 21, 1917	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–75		do		11
	18	do	Center of lake east of can buoy.	2¾	65–70		do		9
	19	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy.	4½	17		do	2	18
	20	Sept. 26, 1917	13 miles SE. by E. of can buoy.	4½	17		Occasional		3
	21	Sept. 13, 1919	Off Presque Isle light	1½, 2¾	60				52
	22	Sept., 16 1919		1½	30		Abundant		49
	23	do	40 miles ESE. of can buoy.	4½	20–30		Only specimens taken in lift.		4
	24	Sept. 18, 1919	14 miles N. by E. of Thunder Bay Island.	2¾	65		do		50
	25	June 30, 1923	17 miles NE. by N. ¾ N. of Thunder Bay Island.	2¾	65–70		do		15
	26	July 2, 1923	20 miles E. by N. of can buoy.	2¾	60–70		do		1
	27	July 5, 1923	18 miles NE. ¾ E. of Thunder Bay Island.	2¾	80–100		do		4
	28	July 7, 1923	13 miles NE. ½ N. of Thunder Bay Island.	2¾	60		do	1	4
	29	July 10, 1923	3 miles E. ½ S. of North Point.	4½	14–20		do	1	6
M. Couture [1] Capt. Pohlkotter	30	November		4½	24–30		Abundant		
Harbor Beach, Mich.	31	Oct. 27, 1917	35 miles NE. by N. ¾ N.	2¾	50	Clay	Occasional		26
	32	Dec. 9, 1917		1½	30		Abundant		25
	33	Mar. 15, 1919		1½	31		66 per cent		92
Tobermory, Ontario. W. Leslie D. McInnis W.W. Ransbury W. J. Simpson J. R. Simpson K. McLeod E. Darragh	34	June	10 miles southwest and west of Cape Hurd.	4½	30		Abundant		
North Channel: J. Merrylees J. Young A. Purvis	35	August	Off Gore Bay Light	4½	20–25		Common		
Georgian Bay:									
Lions Head, Ontario.	36	July 30, 1919	21 miles east of Surprise Shoal.	3	60		Only specimens taken in lift.		43
	37	Oct. 6, 1919	Off White Bluff	3	70		do		52
Wiarton, Ontario.	38	July 28, 1919	4 miles northeast of Cape Croker Light.	3	52		do	2	34
	39	July 30, 1919		3			do	2	38
	40	Nov. 28, 1919	Colpoy Bay	3	10–25		do		7
	41	Dec. 3, 1919	do	1½	15	Mud, rock.	do		25
Borrowed specimens:									
Port Huron, Mich. [2]									2

[1] See note, Table 20.   [2] University of Michigan collection.

TABLE 59.—*Numerical expressions of certain systematic characters for 15 specimens of Leucichthys hoyi from Lake Huron, 10 from depths of about 30 fathoms and 5 from depths of 60 fathoms or more, selected according to size and habitat*

Variety	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O
30-fathom	234	Alpena, Mich.	177	♂	16+27	68	4.4	6.2	11.0	9.8	2.7	8.0	4.3	8.4	1.9	2.1	2.9
	238	do	147	♂	15+26	73	4.3	5.8	9.4	9.6	2.7	8.4	4.5	8.5	1.9	2.1	2.8
	247	do	173	♀	15+28	74	4.2	6.0	10.2	10.1	2.9	8.0	4.2	7.8	1.8	2.1	3.0
	252	do	182	♂	15+27	75	4.2	6.0	9.1	8.7	2.7	9.5	4.5	8.1	1.8	2.1	2.9
	268	do	189	♀	15+26	71	4.3	6.0	10.0	10.5	2.8	8.3	3.8	7.7	2.0	2.2	3.1
	36B	Harbor Beach, Mich.	184	♂	15+27	72	4.2	5.9	10.1	9.8	2.7	8.3	4.0	8.0	1.9	2.0	2.9
	38B	do	161	♂	15+27	74	4.1	5.7	10.0	10.3	2.9	7.3	4.0	8.2	2.0	2.0	2.8
	45B	do	152	♀	15+29	74	4.0	5.5	10.2	10.0	2.8	8.9	3.9	7.6	1.9	2.0	2.8
	58B	do	180	♀	15+27	69	4.1	5.6	9.2	9.4	2.8	8.5	3.7	7.3	1.9	2.0	2.7
	70B	do	163	♀	14+27	72	4.2	5.5	10.5	8.9	2.8	8.3	3.7	8.1	2.2	2.0	2.7
60-fathom	29B	Alpena, Mich.	161	♀	15+26	67	4.0	5.6	10.0	9.0	2.8	8.7	4.2	9.4	2.2	2.0	2.8
	30B	do	161	♂	16+28	79	3.9	5.2	9.7	9.5	3.0	9.4	4.2	8.9	2.1	2.0	2.8
	381	do	158	♀	14+27	79	3.9	5.2	9.7	8.6	3.0	8.4	4.6	10.0	2.1	2.0	2.8
	391	do	151	♀	15+26	78	3.9	5.4	10.7	9.5	3.0	7.7	3.9	10.0	2.5	2.0	2.8
	394	do	170	♀	15+26	73	4.0	5.7	10.6	9.5	3.1	8.4	4.4	9.4	2.1	2.0	2.9

Variety	Field No.	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
30-fathom	234	3.3	4.4	3.6	2.3	3.7	2.0	3.0	5.4	2.6	1.7	2.7	1.9	1.3	9	11	11	15	1.9	1.1	8
	238	3.3	4.4	3.7	2.6	3.9	1.9	3.1	5.4	2.7	1.9	2.9	1.9	1.4	9	11	11	15	1.6	1.0	8
	247	3.2	4.6	3.9	2.5	3.7	1.9	3.5	5.0	2.8	1.7	2.6	2.0	1.4	9	11	11	17	1.6	1.0	9
	252	3.3	4.6	3.8	2.7	3.8	2.1	3.4	5.0	2.7	1.9	2.7	1.9	1.4	9	12	11	16	1.6	.97	8
	268	3.4	4.8	3.9	2.5	3.7	1.9	3.6	5.7	2.8	1.8	2.6	2.0	1.4	10	12	11	15	1.5	1.1	9
	36B	3.2	4.5	3.8	2.5	3.8	1.9	3.1	5.1	2.7	1.8	2.7	1.8	1.3	10	11	11	17	1.6	1.1	8
	38B	3.1	4.4	3.6	2.4	3.9	1.9	3.6	4.8	2.5	1.7	2.8	1.8	1.2	9	10	10	15	1.8	1.1	8
	45B	3.1	4.2	3.6	2.5	4.1	1.9	4.0	5.0	2.7	1.8	3.0	1.9	1.2	9	11	11	14	1.7	1.1	8
	58B	3.2	4.3	3.8	2.5	3.7	1.9	4.0	4.8	2.8	1.8	2.7	2.0	1.3	9	11	11	15	1.5	1.1	9
	70B	3.1	4.2	3.7	2.6	3.8	1.9	3.9	6.2	2.7	1.9	2.8	2.0	1.3	9	12	11	16	1.8	1.0	8
60-fathom	29B	3.1	4.1	3.8	2.5	3.8	1.9	4.8	5.0	2.7	1.7	2.7	1.8	1.3	9	11	12	16	1.7	1.1	8
	30B	3.1	4.4	3.6	2.3	3.7	1.9	4.0	5.1	2.6	1.7	2.6	1.8	1.3	10	12	11	16	1.8	1.1	9
	381	2.9	4.0	4.0	2.5	3.5	1.8	4.3	7.2	2.9	1.8	2.6	1.8	1.2	10	12	11	16	1.6	1.0	8
	391	3.0	4.2	3.8	2.6	3.8	1.9	3.4	5.5	2.7	1.7	2.7	2.0	1.1	9	11	11	17	1.8	1.0	8
	394	3.2	4.4	3.9	2.4	3.8	1.9	3.8	5.0	2.8	1.7	2.7	1.9	1.2	9	11	12	16	1.8	1.1	9

TABLE 60.—*Records of the occurrence of Leucichthys hoyi in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, the abundance of this species in the lift, and the number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Abundance	Bottom	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Sault Ste. Marie, Mich.	1	June 14, 1922	In Whitefish Bay	1½	40–50	Common			
Marquette, Mich.	2	Aug. 8, 1921	6 miles NE. ¾ N	1½	42–65	do	Red clay		28
Ontonagon, Mich.	3	Aug. 24, 1921	21 miles west	2½, 2¾, 4½	15–45	Occasional	do	5	16
	4	Aug. 25, 1921	6 miles NNW	2½, 2¾, 4½	20–38	do	Sand and clay	8	10
Apostle Islands, Wis.	5	July 11, 1922	Between Cat and South Twin Islands.	2½, 2¾	15–20	Only specimen taken in lift.	Sand	1	
	6	July 14, 1922	25 miles north of South Twin Island.	4½	50–90	Occasional	Red and yellow clay.		10
	7	July 15, 1922	14–18 miles NW. by N. of South Twin Island.	4½	40–90	Common	Clay		80
	8	do	20 miles northwest of Rocky Island.	4½	35–65	do	do	1	107
Duluth, Minn.	9	July 17, 1922	20 miles NE. by E	2⅝	30–40	Lift not examined.	Sand	1	1
Grand Marais, Minn.	10	Sept. 14, 1921	Off Terrace Point	2½, 2¾, 4½	30–65	Occasional	Clay	20	10
	11	July 17, 1922	do	4½	30–65	do	do	3	9
Port Arthur, Ontario.	12	Sept. 15, 1923	Thunder Bay, off Thunder Cape.	2½	31	Only specimens taken in lift.	Brownish-gray clay.		3
	13	Sept. 17, 1923	Thunder Bay, south of Welcome Islands.	2½	23	do	do	3	4
	14	Sept. 19, 1923	Thunder Bay, off Sawyer Bay.	2½	49	do	do		10
Rossport, Ontario.	15	Oct. 4, 1921	Off Bread Rock	2½, 2¾	80–90	do	Grayish-brown clay.	1	1
	16	Sept. 29, 1923	Off Salter Island	2½	42	Occasional	Clay		2
Marquette, Mich.[1]								1	

[1] Field Museum collection, borrowed specimen.

TABLE 61.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys hoyi from Lake Superior, selected at random*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53604	Ontonagon, Mich.	216	14+25	♀	69	4.3	5.8	9.7	10.8	2.8	9.0	3.9	6.9	1.7	2.2	3.0	3.4
53616	do	222	16+26	♀	68	4.2	6.0	9.7	10.0	2.8	7.4	4.1	8.2	2.0	2.0	2.9	3.4
53630	do	193	16+25	♀	74	3.7	5.1	9.6	9.1	3.0	8.0	3.7	7.8	2.1	2.0	2.8	2.9
53683	do	203	16+28	♀	69	4.1	5.7	9.6	8.8	2.7	7.8	4.3	9.5	2.2	2.0	2.8	3.1
53774	Grand Marais, Minn.	200	14+24	♂	75	4.0	5.5	8.3	9.1	2.7	8.7	3.7	7.6	2.0	2.0	2.9	3.1
53817	do	223	15+27	♀	79	4.2	6.0	10.1	10.2	2.9	9.6	4.2	7.9	1.8	2.0	3.0	3.3
53599	Ontonagon, Mich.	179	16+27	♀	73	3.8	5.2	9.4	10.4	2.7	7.3	4.0	8.5	2.0	2.0	2.7	3.0
53656	do	159	15+25	♂	72	3.7	4.9	9.9	8.8	2.7	7.5	4.1	8.3	2.0	1.9	2.5	2.8
58293	Apostle Islands, Wis.	169	17+29	♂	78	3.9	5.2	8.8	9.3	2.6	8.0	4.0	8.8	2.2	1.9	2.6	3.0
58458	Grand Marais, Minn.	146	17+27	♀	70	3.7	5.0	9.9	9.9	2.9	7.8	3.8	8.1	2.1	1.9	2.6	2.9

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53604	Ontonagon, Mich.	4.7	3.9	2.5	3.7	1.8	3.5	4.5	2.8	1.8	2.7	1.8	1.4	11	11	12	16	1.8	1.2	8
53616	do	4.8	3.9	2.6	4.3	2.0	3.2	5.6	2.9	1.8	3.0	2.0	1.4	10	10	11	15	1.6	1.1	8
53630	do	4.0	3.8	2.3	3.8	1.8	3.8	5.1	2.8	1.7	2.8	1.5	1.1	9	12	11	16	1.9	1.1	9
53683	do	4.3	3.8	2.4	3.8	1.9	3.1	4.9	2.7	1.7	2.7	1.8	1.2	10	12	11	15	1.8	1.0	9
53774	Grand Marais, Minn.	4.3	3.9	2.3	3.7	1.9	3.8	4.5	2.8	1.7	2.6	1.6	1.1	11	11	11	17	1.5	1.1	8
53817	do	4.8	4.3	2.4	3.9	1.9	3.5	5.7	3.0	1.6	2.7	1.8	1.4	10	11	11	17	1.8	1.1	9
53599	Ontonagon, Mich.	4.1	3.7	2.5	3.7	1.9	3.2	5.7	2.7	1.9	2.7	1.8	1.1	11	11	11	15	2.0	1.1	8
53656	do	3.7	3.6	2.4	3.8	1.9	3.3	4.6	2.7	1.8	2.9	1.6	1.2	9	11	10	16	1.7	1.1	8
58293	Apostle Islands, Wis.	4.1	3.5	2.3	3.6	1.8	3.3	4.5	2.6	1.7	2.7	1.7	1.2	11	11	11	16	1.7	1.2	9
58458	Grand Marais, Minn.	3.9	3.5	2.5	3.8	1.9	3.5	4.8	2.6	1.9	2.9	1.7	1.4	9	10	11	16	1.8	1.2	8

TABLE 62.—*Records of the occurrence of Leucichthys hoyi in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined
1	July 26, 1922	Off Macdiarmid	2½, 2¾	30	[2] 50
2	Aug. 16, 1923	do		18	1
3	Sept. 10, 1923	do			6
4	July 29, 1924	do		15	1
5	Sept. 1, 1923	Off Blackwater River		30	2
6	July 25, 1924	do		54	2
7	Sept. 3, 1923	Humboldt Bay		6–35	[3] 13
8	Aug. 15, 1922	Off Murchison Island		25	2
9	Aug. 1, 1922	Ombabika Bay	4½	15–20	[4] 27
10	Aug. 17, 1922	Off Whitesand River		25	13
11	Aug. 30, 1923	Off Virgin Island		19	3
12	Aug. 3, 1922	Unknown		20–25	3
13	Aug. 5, 1922	do		20–25	2
14	Aug. 15, 1922	do		20–25	11
15	Oct. 26, 1922	do			17
16		No data			18

[1] All but records 1, 9, and 15 from University of Toronto collections.
[2] Eight specimens over 200 millimeters.
[3] One specimen over 200 millimeters.
[4] Two specimens over 200 millimeters.

TABLE 63.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys hoyi from Lake Nipigon, selected according to size*

Field No.	Locality	Length, millimeters	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
57437	Macdiarmid, Ontario	212	16+28	♀	79	4.0	5.4	8.8	8.4	3.0	7.8	4.4	9.6	2.1	2.0	2.7	3.1
57460	do	218	15+27	♀	70	4.0	5.7	10.3	10.0	3.0	8.7	4.1	8.7	2.1	2.0	2.9	3.2
57590	do	215	17+28	♀	78	4.0	5.6	9.3	8.9	2.8	8.6	4.3	8.9	2.0	2.0	2.9	3.1
57615	do	202	16+29	♀	75	3.9	5.4	10.2	9.1	3.0	8.7	4.2	8.4	1.9	1.9	2.8	3.1
57639	do	200	16+28	♀	76	3.8	5.1	9.1	9.0	2.8	7.8	4.2	8.3	1.9	1.9	2.7	3.0
57696	do	153	16+29	♀	79	3.9	5.4	9.2	9.0	3.0	7.7	4.2	9.2	2.1	2.0	2.7	3.1
57704	Ombabika Bay	182	16+29	♂	81	3.8	5.5	9.0	8.2	2.9	9.5	4.0	8.2	2.0	1.9	2.7	2.9
57706	do	175	16+26	♀	77	3.8	5.1	9.7	9.7	2.9	7.9	4.6	9.7	2.1	2.0	2.7	3.0
57709	do	164	16+29	♀	75	3.9	5.0	9.0	9.1	3.0	7.9	4.0	8.2	2.0	2.0	2.6	3.0
57719	do	153	17+29	♂	74	3.9	5.2	9.6	9.5	2.9	8.0	4.6	10.2	2.2	2.0	2.6	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
57437	Macdiarmid, Ontario	4.1	3.8	2.3	3.5	1.8	3.0	5.3	2.8	1.6	2.6	1.4	1.2	10	12	11	15	1.7	1.2	9
57460	do	4.6	3.9	2.4	3.8	1.8	3.2	5.4	2.7	1.6	2.7	1.6	1.2	8	10	11	16	2.1	1.4	9
57590	do	4.3	3.7	2.4	3.7	1.8	3.3	5.7	2.7	1.7	2.7	1.7	1.3	10	11	11	15	1.7	1.1	9
57615	do	4.2	3.9	2.3	3.5	1.9	3.5	4.3	2.8	1.6	2.6	1.7	1.2	9	12	11	16	2.0	1.2	9
57639	do	4.1	4.0	2.3	3.6	1.8	3.0	4.9	3.0	1.7	2.7	1.6	1.2	10	11	12	15	1.8	1.2	9
57696	do	4.3	3.5	2.3	3.8	1.8	3.6	4.8	2.5	1.7	2.8	1.5	1.3	10	12	11	15	1.7	1.1	9
57704	Ombabika Bay	4.2	3.8	2.3	3.8	1.9	3.3	4.7	2.7	1.6	2.7	1.6	1.2	10	12	11	17	1.8	1.2	9
57706	do	4.0	4.0	2.4	3.5	1.8	3.4	5.6	3.0	1.7	2.6	1.8	1.1	10	11	11	15	1.7	1.3	9
57709	do	3.9	3.5	2.3	3.4	1.8	3.5	4.2	2.7	1.8	2.7	1.6	1.1	10	11	11	16	1.8	1.3	9
57719	do	4.0	3.5	2.2	3.8	1.8	3.9	4.8	2.6	1.7	2.8	1.4	1.1	9	11	11	16	1.8	1.3	9

TABLE 64.—*Records of the occurrence of Leucichthys hoyi in Lake Ontario*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, the abundance of this species in the lift, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Percentage	Preserved specimens examined: +200 mm.	Preserved specimens examined: −200 mm.
Winona, Ontario	1	Nov. 23, 1917		2½			(1)	1	
Bronte, Ontario	2	June 29, 1921	13 miles E. ½ S	2½, 2¾	40–50	Mud	(1)	7	1
	3	June 30, 1921	Off Oakville	4¾	16			1	1
Brighton, Ontario	4	June 10, 1921	20 miles S. by W. of Presque Isle Light.	2½	40–50	Mud	(2)	13	3
	5	June 16, 1921	do	2½	40–50	do	(3)	12	
Sandy Pond, N. Y.	6	Aug. 24, 1923	9 miles west	3	25–28	Sand and mud	(1)	5	
	7	Aug. 30, 1923	14 miles west	1½, 2½, 3, 3¼, 3½	60	Clay and mud	(1)	14	1
Selkirk, N. Y.	8	July 11, 1921	5 miles NNW. of Nine-Mile Point.	3	25–35	Blue clay	(1)	8	2
Oswego, N. Y.	9	Sept. 1, 1923	Off Nine-Mile Point	3	30	Clay	(1)	7	2
	10	Sept. 4, 1923	8½ miles W. by N. ½ N	1½, 2½, 3	70–75	Clay and mud	(1)		4
Sodus Point, N. Y.	11	July 12, 1921	8½ miles NNW	2½, 2¾	60	Mud and clay	75	70	4
	12	July 13, 1921	NNW	3	40	Mud	(1)		
Charlotte, N. Y.	13	July 4, 1921	7 miles off Braddock Point Light.	2½, 2¾	65	Blue and brown clay.	66	58	
Wilson, N. Y.	14	June 23, 1921	3 miles north	2½, 2¾	30	Brown clay	(1)	4	
	15	June 25, 1921	5 miles north	2½, 2¾	50	Clay and mud	60	23	1
	16	July 16, 1921	do	2½, 2¾	50	Clay	90		
	17	July 19, 1921	6½ miles N. by W. ½ W	2½, 2¾	65	Blue and brown clay.	25	7	3
	18	July 21, 1921	2 miles north	2½	20		(1)	5	
Toronto, Ontario [4]								1	

[1] Rare.
[2] Occasional.
[3] Common.
[4] U. S. National Museum collection.

TABLE 65.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys hoyi from Lake Ontario, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53194	Brighton, Ontario	128	14+28	♀	75	3.7	4.9	10.0	9.7	2.9	7.5	4.5	9.8	2.1	1.9	2.5	2.8
53277	Bronte, Ontario	167	16+30	♀	76	3.9	5.5	10.9	9.8	3.0	8.3	4.1	9.2	2.2	2.0	2.9	3.1
54079	Wilson, N. Y.	164	17+29	♀	75	3.9	5.1	9.6	9.6	2.7	9.6	3.8	8.6	2.2	1.9	2.5	3.0
62468	Sandy Pond, N. Y.	183	16+28	♀	73	3.8	5.3	9.8	8.7	3.0	8.3	4.3	10.1	2.3	2.0	2.7	3.0
54124	Sodus Point, N. Y.	219	18+30	♀	71	4.0	5.6	8.7	8.7	2.6	8.5	3.9	7.5	1.9	1.9	2.7	3.0
54165	do	196	15+25	♂	67	4.0	5.4	9.7	9.2	2.7	8.1	3.7	7.2	1.9	2.0	2.8	3.1
54139	do	214	15+27	♀	69	4.1	5.7	8.9	9.2	2.7	8.9	3.6	7.9	2.1	2.2	3.0	3.3
54159	do	208	16+30	♀	76	4.1	5.9	10.0	9.0	2.8	9.0	4.1	8.6	2.0	2.0	2.9	3.3
54200	do	253	16+28	♀	74	4.4	6.1	10.2	11.9	2.8	8.8	4.0	8.1	2.0	2.2	3.1	3.4
54205	do	253	15+28	♀	71	4.2	6.0	10.5	10.2	2.7	8.7	3.9	7.9	2.0	2.1	2.9	3.4

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53194	Brighton, Ontario.	3.7	3.7	2.6	3.6	1.8	4.1	4.2	2.8	2.0	2.8	1.5	1.3	9	10	11	15	1.8	1.1	8
53277	Bronte, Ontario	4.3	3.8	2.8	4.1	1.9	4.2	4.7	2.7	2.0	2.9	1.9	1.4	9	10	10	15	1.9	1.0	9
54079	Wilson, N. Y.	4.0	3.8	2.4	3.5	1.8	3.8	4.6	2.9	1.8	2.7	1.7	1.2	9	----	11	16	1.7	------	9
62468	Sandy Pond, N. Y.	4.1	3.9	2.6	3.6	1.8	4.7	5.7	2.8	1.8	2.6	2.0	1.1	9	11	10	14	1.6	1.0	8
54124	Sodus Point, N. Y.	4.2	4.2	2.7	3.6	1.9	4.1	4.6	3.0	1.9	2.6	1.6	1.3	9	11	11	16	1.4	1.0	8
54165	do	4.2	4.3	2.6	3.7	1.9	3.7	5.4	3.2	1.9	2.7	1.7	1.2	9	11	10	14	1.6	1.0	9
54139	do	4.5	4.1	2.4	3.7	1.8	4.2	4.6	3.0	1.7	2.7	1.7	1.3	9	12	11	14	1.4	1.0	8
54159	do	4.7	4.1	2.5	3.7	1.9	4.0	4.9	2.9	1.7	2.6	2.2	1.4	9	11	10	15	1.5	.95	9
54200	do	4.8	4.2	2.6	3.9	2.0	4.3	5.1	3.0	1.9	2.8	2.0	1.5	9	10	11	15	1.5	1.2	8
54205	do	4.7	4.4	2.5	3.6	1.9	3.4	4.5	3.1	1.8	2.6	2.0	1.5	9	10	11	14	1.6	1.0	8

TABLE 66.—*Records of the occurrence of Leucichthys artedi in Lake Erie*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Port from which nets were set	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined	
					+225 mm.	−225 mm.
Monroe, Mich.	1920				11	1
Sandusky, Ohio	Nov. 29, 1920		3		16	3
Ashtabula, Ohio	Oct. 20, 1920	S. by W. of breakwater	3	5–7	3	1
	Oct. 22, 1920	14 miles NE. by N.	3	12	1	1
	Oct. 23, 1920	do	3	12	3	1
Erie, Pa	Oct. 24, 1920	12 miles N. by E.	3		6	1
	do	19 miles NNE.	3		1	23
	Oct. 25, 1920	17 miles NE. by N. ½ N.	3	20–25	6	41
	Oct. 26, 1920	22 miles NE. ½ N.	3		1	
Dunkirk, N. Y.	Oct. 27, 1920	12 miles NW. by N.	3	24	14	5
	Oct. 28, 1920	14 miles W. by N.	3	25	5	35
Port Stanley, Ontario	Dec. —, 1922	West of the port	3		59	3
Erieau, Ontario	Dec. 3, 1924		3		25	
Borrowed specimens:						
Erie, Pa.[1]					22	
Do.[2]					3	
Cleveland, Ohio [2]					1	
Port Stanley, Ontario [2]					1	
Port Maitland, Ontario [3]					7	1
Port Dover, Ontario [3]					7	1
Merlin, Ontario [3]					1	

[1] Field Museum collection. [2] U. S. National Museum collection. [3] University of Toronto collection.

TABLE 67.—*Numerical expressions of certain systematic characters for 40 specimens of Leucichthys artedi from Lake Erie, 30 of them over 200 millimeters long and 10 under 200 millimeters long, selected according to size and locality*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB
Albus form:										
East end, over 200 mm.	4049	Ashtabula, Ohio	225	Im. ♀	17+31	71	4.2	6.0	8.0	7.8
	4050	do	293	♀	18+30	77	4.5	6.5	8.3	8.9
	4051	do	277	♀	17+29	77	4.7	6.9	9.5	10.5
	4056	do	249	♀	18+30	74	4.4	6.3	9.5	9.6
	4060	Erie, Pa	247	♀	18+31	80	4.2	6.0	9.5	8.8
	4096	do	255	♀	17+30	75	4.5	6.7	10.0	10.5
	4114	do	234	♂	17+31	76	4.5	6.1	10.0	10.6
	4136	do	315	♀	17+28	76	4.6	6.7	9.0	9.0
	4145	Dunkirk, N. Y	231	♂	18+30	76	4.3	6.1	9.2	8.7
	4158	do	283	♂	18+30	72	4.6	6.5	8.8	8.5
West end	59330	Port Stanley, Ontario	276	♂	17+29	75	4.4	6.0	8.1	7.8
	59336	do	241	♀	16+30	69	4.4	6.2	8.0	9.3
	59351	do	305	♂	16+29	75	4.5	6.6	8.0	8.2
	59353	do	299	♀	16+28	77	4.7	6.6	8.3	9.9
	59364	do	282	♂	18+31	73	4.6	6.7	7.8	8.9
	59370	do	256	♀	18+30	75	4.4	6.5	7.7	8.8
	59372	do	250	♀	16+27	76	4.5	6.2	8.8	10.5
	59378	do	264	♀	16+30	81	4.7	6.6	8.0	7.8
	59380	do	231	♀	17+31	77	4.6	6.2	8.5	9.2
	59384	do	237	♂	17+27	72	4.4	6.3	8.7	8.4
Artedi form:										
Bluebacks	4600	Sandusky, Ohio	297	♂	16+29	77	4.6	6.3	9.5	9.9
	4602	do	305	♀	19+31	76	4.8	7.0	10.8	9.8
	52802	Monroe, Mich	302	♀	16+30	84	4.9	7.1	11.5	10.2
	52803	do	229	♂	18+32	89	4.5	6.5	10.1	11.9
	52806	do	234	♀	18+31	83	4.5	6.1	11.2	10.1
	52807	do	258	♂	16+30	82	4.6	6.4	10.0	10.2
	52808	do	254	♂	17+30	81	4.7	6.5	9.6	9.4
	52809	do	315	♂	19+30	78	5.0	7.1	10.1	9.9
	52812	do	260	♀	17+30	85	4.6	6.1	9.6	9.2
	52813	do	341	♀	16+30	84	5.2	7.4	12.1	11.3
Albus form:										
Under 200 mm	4057	Ashtabula, Ohio	181	♂	17+29	83	4.3	6.2	7.9	8.9
	4070	do	196	♂	16+29	73	4.4	5.9	9.2	8.9
	4102	Erie, Pa	168	Im. ♀	15+30	73	4.3	6.1	8.8	8.4
	4106	do	184	♂	16+28	77	4.2	5.7	9.2	9.4
	4130	do	194	♀	16+30	80	4.2	5.7	9.1	9.7
	4131	do	160	Im. ♀	18+29	74	4.1	5.9	8.9	8.9
	4137	do	193	♀	17+29	78	4.3	5.9	8.9	9.1
	4139	do	185	♀	16+28	71	4.3	6.1	9.7	8.4
	4147	Dunkirk, N. Y	128	Im. ♂	17+30	78	4.2	6.0	8.6	9.2
	4171	do	188	♀	17+28	75	4.2	5.8	9.6	9.4

Size	Field No.	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
Albus form:															
East end, over 200 mm	4049	2.6	7.2	3.0	6.4	2.0	2.1	3.1	3.2	4.7	4.3	2.8	4.0	2.1	3.0
	4050	2.6	9.7	3.4	6.6	1.9	2.3	3.3	3.6	5.2	4.3	2.6	4.0	2.0	3.5
	4051	3.0	7.3	3.6	7.1	1.9	2.4	3.5	3.7	5.5	4.5	2.9	3.9	2.1	2.9
	4056	2.8	9.2	3.5	7.3	2.0	2.4	3.4	3.5	5.0	4.3	2.6	4.0	2.1	3.7
	4060	2.7	8.2	3.3	7.4	2.2	2.1	3.0	3.3	4.7	4.2	2.7	4.0	2.0	3.1
	4096	2.9	8.5	3.6	7.7	2.0	2.2	3.3	3.6	5.4	4.4	2.8	3.7	2.1	3.4
	4114	2.8	8.0	4.0	8.0	2.0	2.3	3.1	3.6	5.0	4.2	2.6	4.0	2.0	3.2
	4136	2.8	7.8	3.3	6.7	2.0	2.3	3.3	3.5	5.1	4.5	2.9	4.5	2.1	2.8
	4145	3.0	7.2	3.7	7.8	2.0	2.1	3.0	3.5	5.1	4.0	2.6	4.0	1.9	2.9
	4158	2.7	9.1	3.3	6.5	1.9	2.3	3.2	3.8	5.4	4.6	2.8	3.9	2.1	3.4
West end	59330	2.6	6.5	2.8	5.8	2.0	2.1	2.9	3.4	4.5	4.5	2.6	3.9	2.0	2.5
	59336	2.8	7.4	3.5	7.3	2.0	2.1	3.0	3.5	5.0	4.8	2.8	3.9	2.1	2.7
	59351	2.8	9.5	3.0	6.4	2.1	2.3	3.4	3.5	5.1	4.9	2.8	3.9	2.1	3.1
	59353	2.5	8.4	3.4	6.6	1.9	2.4	3.4	3.7	5.2	4.8	2.9	3.8	2.1	2.8
	59364	2.7	6.8	3.6	7.6	2.1	2.1	3.1	3.5	5.2	4.6	2.9	4.0	2.2	3.0
	59370	2.7	8.3	3.2	6.7	2.1	2.2	3.3	3.5	5.2	4.5	3.1	4.0	2.1	3.0
	59372	2.8	7.8	3.7	6.7	1.7	2.3	3.2	3.5	4.8	4.2	2.8	4.1	2.0	2.8
	59378	2.7	9.1	3.7	6.9	1.8	2.3	3.2	3.8	5.3	4.3	2.8	3.8	2.0	3.1
	59380	2.8	7.4	3.7	7.0	1.8	2.3	3.2	3.7	5.0	4.2	2.7	3.8	2.0	2.8
	59384	2.8	7.9	3.1	6.0	1.9	2.3	3.3	3.4	4.9	4.4	2.9	4.1	2.2	3.3
Artedi form:															
Bluebacks	4600	2.7	8.7	4.1	7.0	1.7	2.3	3.1	3.6	4.9	4.5	3.0	3.9	2.2	3.7
	4602	2.7	9.2	3.7	6.4	1.7	2.4	3.5	3.9	5.6	4.4	3.1	4.2	2.2	3.4
	52802	2.5	7.9	4.1	7.5	1.8	2.3	3.4	3.8	5.5	4.3	3.0	3.8	2.1	3.8
	52803	2.6	7.6	4.8	8.8	1.8	2.2	3.2	3.6	5.1	4.1	2.8	3.7	2.0	4.2
	52806	2.8	7.8	4.0	8.3	2.0	2.2	3.1	3.5	4.7	4.1	2.7	3.7	2.0	3.7
	52807	2.8	7.8	4.0	8.0	2.0	2.4	3.3	3.7	5.1	4.4	2.6	3.6	2.0	3.3
	52808	2.6	7.6	4.2	8.1	1.9	2.2	3.1	3.6	5.1	4.2	2.9	3.8	2.0	3.3
	52809	2.6	8.2	4.3	7.0	1.6	2.4	3.4	4.0	5.7	4.5	3.0	4.1	2.2	3.5
	52812	2.7	8.9	4.0	8.1	2.0	2.3	3.1	3.6	4.8	4.3	2.6	3.6	2.0	3.2
	52813	2.7	8.1	4.1	7.2	1.7	2.6	3.6	4.1	5.8	4.5	3.0	4.0	2.1	3.3

TABLE 67.—*Numerical expressions of certain systematic characters for 40 specimens of Leucichthys artedi from Lake Erie, 30 of them over 200 millimeters long and 10 under 200 millimeters long, selected according to size and locality*—Continued

Size	Field No	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
Albus form: Under 200 mm	4057	2.7	8.6	3.6	7.8	2.1	2.1	3.1	3.4	4.9	4.2	2.8	4.0	2.1	3.7
	4070	2.7	8.5	3.8	8.5	2.2	2.2	3.0	3.5	4.6	3.7	2.7	4.0	2.0	3.3
	4102	2.9	8.4	3.8	8.8	2.3	2.1	3.0	3.4	4.8	4.2	2.8	4.2	2.0	4.2
	4106	2.7	9.4	3.9	8.7	2.1	2.1	2.9	3.3	4.5	3.8	2.7	3.9	2.0	3.5
	4130	2.8	8.4	3.9	8.0	2.0	2.1	2.8	3.4	4.5	4.0	2.8	3.9	2.0	3.7
	4131	2.8	8.0	3.8	8.0	2.1	2.1	3.0	3.3	4.7	4.1	2.8	3.8	2.1	3.5
	4137	2.7	7.4	3.7	8.0	2.1	2.2	3.0	3.4	4.6	3.8	2.7	3.9	2.0	2.9
	4139	3.0	9.2	4.2	8.0	1.9	2.3	3.3	3.4	4.9	3.9	2.8	3.9	2.0	3.9
	4147	2.8	8.5	4.2	9.1	2.1	2.1	3.0	3.2	4.6	4.0	2.9	4.1	2.1	3.3
	4171	2.9	8.1	3.8	7.5	1.9	2.2	3.0	3.4	4.7	4.0	2.5	3.7	1.9	3.0

Size	Field No.	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Scale rows		
Albus form: East end, over 200 mm	4049	5.4	3.0	1.9	2.8	1.7	1.5	10	12	11	15	1.4	0.90	8	42	35	26
	4050	5.2	3.0	1.8	2.7	2.0	1.9	11	11	11	14	1.3	.92	8	40	32	25
	4051	5.8	3.0	2.0	2.6	2.1	1.9	9	10	11	16	1.4	1.0	8	41	32	25
	4056	5.0	3.0	1.8	2.7	2.0	1.7	10	12	11	16	1.5	1.0	8	42	33	24
	4060	4.9	2.9	1.9	2.8	1.9	1.4	9	11	11	16	1.6	1.0	8	40	32	24
	4096	5.0	3.0	1.9	2.5	2.0	1.7	9	10	11	14	1.5	1.1	7	41	32	24
	4114	5.2	3.1	1.9	2.9	1.8	1.6	9	10	11	16	1.5	1.1	9	42	32	25
	4136	4.8	3.1	2.0	3.1	1.9	1.6	10	11	11	16	1.4	1.0	9	45	32	24
	4145	5.3	2.8	1.8	2.8	1.9	1.6	9	11	11	16	1.5	.95	8	41	34	25
	4158	5.5	3.2	2.0	2.7	2.1	1.7	11	12	11	15	1.5	1.0	8	39	31	23
West end	59330	5.6	3.4	2.0	2.9	1.8	1.5	10	12	11	15	1.3	.92	7	40	31	24
	59336	5.4	3.4	2.0	2.7	1.9	1.6	10	10	11	15	1.4	1.1	8	40	32	24
	59351	4.7	3.4	1.9	2.7	2.0	1.5	10	12	12	14	1.3	.91	8	42	33	25
	59353	5.4	3.4	2.1	2.7	2.0	1.6	10	11	11	15	1.3	1.0	8	38	32	24
	59364	6.1	3.1	2.0	2.8	2.1	1.7	10	11	11	17	1.2	.95	8	40	32	24
	59370	5.7	3.1	2.1	2.7	1.7	1.8	11	11	11	16	1.3	1.0	8	42	33	25
	59372	5.9	3.0	2.0	3.0	2.0	1.5	11	10	11	15	1.3	1.0	8	41	35	25
	59378	5.8	3.1	2.0	2.7	2.0	1.9	11	13	11	15	1.3	.80	8	41	33	25
	59380	5.4	3.1	2.0	2.8	2.1	1.7	11	11	11	16	1.4	1.0	8	39	32	24
	59384	5.8	3.1	2.0	2.9	2.0	1.4	10	11	12	16	1.5	1.0	8	41	32	24
Artedi form: Bluebacks	4600	5.7	3.3	2.2	2.9	2.4	1.9	9	11	11	16	1.3	.86	8	44	36	27
	4602	5.7	3.0	2.1	2.9	2.5	1.9	9	12	11	16	1.6	1.0	8	42	34	25
	52802	6.1	3.0	2.1	2.6	2.5	1.9	8	10	11	15	1.5	.88	8	43	33	25
	52803	5.0	2.9	1.9	2.6	2.2	1.7	10	10	12	16	1.4	1.0	9	44	34	25
	52806	5.0	3.0	2.0	2.7	2.2	1.7	9	11	11	17	1.6	1.0	8	44	36	27
	52807	5.0	3.2	1.9	2.6	2.2	1.7	10	11	11	18	1.4	1.0	7	45	34	26
	52808	5.6	3.0	2.0	2.7	2.2	1.7	10	11	11	16	1.3	.88	8	45	35	26
	52809	5.7	3.1	2.0	2.8	2.4	2.0	10	11	12	16	1.5	.94	8	43	34	25
	52812	4.6	3.2	2.0	2.7	2.1	1.8	11	12	11	17	1.4	.91	8	43	34	26
	52813	5.4	3.2	2.1	2.8	2.5	2.1	8	10	11	16	1.5	.93	8	46	36	26
Albus form: Under 200 mm	4057	6.0	2.9	2.0	2.7	2.0	1.5	11	11	10	14	1.3	1.0	7	40	32	24
	4070	5.5	2.7	2.0	3.0	1.8	1.5	10	12	11	16	1.6	1.0	8	40	32	23
	4102	5.0	3.0	2.0	3.0	1.9	1.6	9	12	11	14	1.5	1.0	8	40	32	24
	4106	5.7	2.8	2.0	2.9	1.7	1.3	9	11	11	15	1.6	1.1	7	42	34	25
	4130	5.0	3.0	2.0	2.9	1.9	1.6	11	12	12	15	1.4	1.0	8	41	33	24
	4131	5.3	2.9	2.0	2.7	1.9	1.4	10	11	11	15	1.6	1.0	7	40	33	24
	4137	5.5	2.8	2.0	2.9	1.8	1.5	11	11	11	16	1.5	1.0	7	40	32	24
	4139	5.2	2.7	2.0	2.7	1.9	1.4	10	12	12	15	1.6	.94	8	41	33	24
	4147	5.7	2.8	2.0	2.9	1.8	1.4	10	10	11	14	1.5	1.0	7	42	33	24
	4171	5.0	2.9	1.8	2.7	1.7	1.4	9	11	10	15	1.8	1.2	8	41	31	23

Table 68.—*Records of the occurrence of Leucichthys artedi in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of bottom where made, percentage of this species in the lift, and total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Percentage of artedi	Preserved specimens examined	
								+225 mm.	−225 mm.
Menominee, Mich.	1	Aug. 16, 1920	Off Little Sturgeon	2⅜, 2½	11		100	4	1
	2	do	8 miles south of Green Island	2⅜	16		100	13	2
Oconto, Wis.	3	Nov. 17, 1920	4 miles northeast	2⅜	2		100	7	3
	4	do	3 miles southeast	(1)	5–6		100	14	10
Washington Harbor, Wis.	5	Aug. 18, 1920	4 miles west of Boyer Bluff	2⅜	18–24		45	10	2
	6	do	7 miles NNW.	2⅝	11				2
	7	do	5 miles west of Boyer Bluff	4	20	Rock	(2)		2
	8	Aug. 19, 1920	3 miles WNW. of Boyer Bluff	4	20–24			3	
	9	do	20 miles E. ½ N. of Rock Island	2½, 2⅝	71–90	Clay, mud	(3)		1
	10	do	Off northwest end of St. Martin's Island.	4½	14	Rock	(2)		32
Sturgeon Bay, Wis.	11	Aug. 23, 1920	12 miles E. by S. of ship-channel mouth.	2⅝, 2¾	60–70	Mud	(3)		
Algoma, Wis.	12	Aug. 24, 1920	10 miles E. by N.	2½	35–50	Gravel, mud	(3)		
Port Washington, Wis.	13	Sept. 25, 1920	18 miles E. ½ S.	2½	65–48	Clay	(3)		
	14	Sept. 27, 1920	Off city	(1)	5		(4)	10	1
Milwaukee, Wis.	15	Mar. 24, 1919		2½	10–15		(4)	8	
	16	do		2½	50		(5)	1	
	17	Sept. 24, 1920	9 miles NNE.	2½	22–25	Clay	(5)		
	18	Nov. 15, 1920	5 miles E. by S½ S.	2½	12		(6)	4	1
Michigan City, Ind.	19	Sept. 3, 1920	22 miles NWN. ½ N.	2½	30–40	Clay	(3)	1	
	20	Sept. 4, 1920	Off city	(1)	5	Sand	(4)	7	
	21	Oct. 11, 1920	20 miles N. by W. ¾ W.	2½	30–40	Mud, clay	(3)		
	22	Mar. 2, 1921	14 miles NNW.	1½	26	Clay	(6)		5
	23	Mar. 4, 1921	15 miles NW. by N. ½ N.	2½	28		(6)	4	
Muskegon, Mich.	24	Aug. 31, 1920		2¾				1	
Manistee, Mich.	25	Aug. 27, 1920	3 miles south	(1)	4	Sand	(3)	2	
Platte Bay, Mich. (field station).	26	July 21, 1923	1½ miles south of Otter Creek	1½	8–12	do	(2)		1
	27	July 23, 1923	do	1½	15–25	do	(2)		12
South Manitou Island, Mich.	28	July 30, 1923	Off the light	[1, 7] 1½	1–5		(3)	1	
Northport, Mich.	29	June 22, 1920	5 miles northwest of Cathead Light.	2¾	40–60		(2)		1
	30	June 23, 1920	Off Northport Point	1½	28–40		(2)		3
	31	July 31, 1923	5 miles northwest of Cathead Light.	2¾	40–60		(2)	4	
Traverse City, Mich.	32	June 22, 1920	4 miles north on east shore of West Bay.	(1)	4	Sand	(6)	3	
	33	June 25, 1920	do	(1)	4	do	(6)	6	4
	34	July 25, 1923	Off Lees Point	1½	4–6		(2)		2
	35	do	do	(7)	1		(2)	1	
	36	do	do	1½	6–16		(2)		1
	37	July 18, 1923	West Bay	1½	30–40	Clay	(3)		
	38	July 19, 1923	Barrow Harbor	(1)	5		(2)	11	3
	39	July 26, 1293	do	(1)	5		(2)	2	12
	40	do	1½ miles south of Barrow Harbor.	(1)	5		(6)		25
Manistique, Mich.	41	Aug. 11, 1920	13 miles SE. ½ E.	4½	20	Sand			11
Seul Choix, Mich.	42	Aug. 20, 1920	1½ miles west of Seul Choix Point.	(1)	5–8		(3)	7	
Borrowed specimens:									
Jackson Park Lagoon, Chicago, Ill.[8]								4	
Chicago, Ill.[8]								2	
Whiting, Ind.[8]									1
Green Bay[8]								14	2
Pine, Ind.[9]								1	

[1] Pound net.
[2] Only specimens taken in lift.
[3] Rare.
[4] Common.
[5] Lift not examined or percentage not ascertained.
[6] Occasional.
[7] Seine.
[8] Field Museum collection.
[9] U. S. National Museum collection.

TABLE 69.—*Numerical expressions of certain systematic characters for 19 specimens of Leucichthys artedi from Lake Michigan over 200 millimeters in length and for 10 specimens under 200 millimeters long, selected according to size and locality*

[Ten of the larger fish are from Green Bay, half from deep water, and half from the shoals, and nine of them from Lake Michigan proper]

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA
		Green Bay:									
Over 200 millimeters.	3038	Menominee, Mich. (deep water)	242	16+30	♀	83	4.6	6.5	9.6	10.1	2.7
	3042	do	248	15+28	♂	76	4.5	6.2	9.2	9.1	2.8
	3046	do	253	17+32	♀	79	4.5	6.4	9.4	10.3	2.6
	3049	do	257	19+34	♀	84	4.5	6.4	8.8	9.9	2.7
	3057	do	285	18+30	♀	82	4.5	6.4	11.1	8.9	2.5
	4290	Oconto, Wis. (shallow water)	257	18+31	♀	82	4.3	6.2	10.3	9.3	2.6
	4294	do	258	17+30	♂	83	4.4	6.2	8.4	8.8	2.7
	4307	do	256	18+32	♀	83	4.7	6.4	10.5	9.8	2.6
	4310	do	252	17+32	♂	78	4.4	6.1	10.8	9.0	2.8
	4314	do	280	16+28	♂	89	4.6	6.6	9.6	10.5	2.6
		Lake Michigan proper:									
	1638	Milwaukee, Wis	255	19+31	♂	93	4.5	6.2	9.8	10.9	2.6
	1645	do	256	18+35	♂	77	4.4	6.0	10.2	10.6	2.7
	2792	Traverse City, Mich	248	18+29	Im. ♀	85	4.6	6.3	9.6	9.2	2.6
	3525	Michigan City, Ind	270	18+31	♀	81	4.5	6.1	10.7	10.3	2.7
	3556	do	258	19+32	♀	79	4.4	6.4	11.2	11.2	2.7
	3558	do	248	17+32	♀	81	4.2	6.0	9.7	10.6	2.6
	3607	Milwaukee, Wis	244	19+34	♀	79	4.2	5.9	10.9	11.0	2.7
	3724	Port Washington, Wis	255	18+31	♀	82	4.4	6.1	9.6	10.2	2.8
	4585	Seul Choix, Mich	289	17+30	♂	80	4.6	6.0	9.9	9.7	2.8
Under 200 millimeters.	3102	Washington Harbor, Wis	157	17+29	Im. ♀	83	4.4	6.5	11.2	9.3	2.9
	3228	do	188	16+29	♂	77	4.0	5.6	11.6	11.0	2.8
	3236	do	194	17+31	♀	71	4.3	5.8	8.8	8.0	2.6
	3252	do	163	17+31	♂	83	4.2	5.9	10.1	9.7	2.7
	59590	Traverse City, Mich	178	20+33	Im. ♂	86	4.5	6.3	9.3	9.8	2.7
	59592	do	165	18+34	Im. ♀	89	4.4	6.1	10.3	11.0	2.7
	59612	do	178	19+33	Im. ♂	83	4.5	6.2	11.8	10.9	2.7
	59614	do	177	16+29	♀	85	4.3	5.9	9.5	9.7	2.8
	59617	do	174	18+33	Im. ♂	85	4.5	6.2	11.2	10.2	2.8
	59690	do	198	15+28	♀	85	4.4	6.0	10.4	10.0	2.9

Size	Field No.	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
Over 200 millimeters	3038	7.8	3.6	7.8	2.1	2.3	3.2	3.7	5.1	4.0	3.0	4.0	2.1	3.9
	3042	7.7	3.9	7.2	1.8	2.2	3.1	3.6	4.9	4.2	2.5	3.7	1.9	3.2
	3046	8.0	4.0	7.6	1.8	2.2	3.1	3.6	5.0	4.1	3.0	4.1	2.1	4.2
	3049	8.5	3.8	8.5	2.2	2.1	3.0	3.5	5.0	4.2	3.0	4.0	2.2	4.3
	3057	8.3	4.4	7.9	1.7	2.2	3.1	3.4	4.8	4.1	2.9	3.9	2.1	4.8
	4290	9.1	4.2	7.5	1.7	2.1	3.1	3.3	4.7	4.2	3.0	4.2	2.1	4.5
	4294	8.1	4.2	7.5	1.7	2.1	3.0	3.4	4.8	4.2	2.9	4.1	2.1	4.5
	4307	7.7	4.1	7.2	1.7	2.3	3.2	3.6	4.9	4.1	3.0	4.0	2.1	3.4
	4310	8.0	4.5	8.6	1.9	2.1	2.9	3.4	4.8	4.2	2.8	3.7	2.0	3.6
	4314	8.4	4.5	8.4	1.8	2.3	3.3	3.6	5.2	4.2	2.9	4.0	2.1	3.7
	1638	8.7	4.3	7.7	1.7	2.1	2.9	3.5	4.8	4.0	2.7	3.7	2.0	4.7
	1645	7.8	4.8	8.5	1.7	2.1	2.9	3.4	4.7	3.9	2.9	4.0	2.1	4.1
	2792	7.5	4.6	8.5	1.8	2.2	3.0	3.6	4.8	4.0	2.8	4.0	2.0	3.5
	3525	8.7	5.0	8.7	1.7	2.1	2.9	3.5	4.8	4.3	2.9	4.0	2.2	4.6
	3556	8.1	4.8	9.2	1.8	2.1	3.1	3.4	4.9	4.3	3.1	4.2	2.2	4.1
	3558	8.2	5.0	9.1	1.8	2.0	3.0	3.1	4.5	4.2	2.8	3.9	2.1	4.6
	3607	8.1	4.9	7.8	1.5	2.1	2.9	3.2	4.1	4.1	2.9	3.8	2.1	4.0
	3724	8.5	4.9	9.1	1.8	2.1	3.0	3.4	4.7	4.1	2.8	3.8	2.0	4.4
	4585	8.2	4.7	7.8	1.6	2.3	3.0	3.6	4.7	4.0	2.8	3.6	2.1	4.1
Under 200 millimeters	3102	7.4	5.4	9.8	1.8	2.1	3.1	3.2	4.7	4.1	2.8	3.8	2.0	3.5
	3228	7.5	4.9	9.4	1.9	2.0	2.7	3.0	4.2	3.8	2.7	3.6	2.0	4.1
	3236	7.7	4.4	8.4	1.9	1.9	2.6	3.1	4.2	3.9	2.7	3.8	2.0	3.6
	3252	8.8	5.0	9.0	1.7	2.0	2.8	3.2	4.5	3.8	2.7	3.7	2.0	4.2
	59590	7.4	4.9	9.3	1.8	2.2	3.1	3.4	4.7	4.2	2.8	3.7	1.9	4.2
	59592	7.5	5.0	9.2	1.7	2.1	3.0	3.4	4.7	4.1	2.8	3.7	2.0	4.0
	59612	7.1	5.0	8.9	1.7	2.2	3.0	3.4	4.7	4.1	3.0	3.9	2.0	3.9
	59614	8.4	4.6	8.4	1.8	2.1	3.0	3.3	4.6	3.9	2.9	3.7	2.0	4.5
	59617	7.9	4.7	8.7	1.8	2.2	3.1	3.4	4.7	4.2	2.9	3.8	2.0	3.8
	59690	7.9	4.5	8.8	1.9	2.2	3.0	3.3	4.5	3.8	2.6	3.6	1.9	3.9

TABLE 69.—*Numerical expressions of certain systematic characters for 19 specimens of Leucichthys artedi from Lake Michigan over 200 millimeters in length and for 10 specimens under 200 millimeters long, selected according to size and locality*—Continued

Size	Field No.	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Over 200 millimeters	3038	5.8	2.8	2.1	2.8	2.4	1.7	11	13	11	15	1.4	0.98	8
	3042	6.1	3.0	1.8	2.7	2.0	1.5	10	11	10	15	1.4	1.0	8
	3046	6.0	2.9	2.1	2.9	2.2	1.7	10	12	12	16	1.4	1.0	8
	3049	7.0	3.0	2.1	2.8	2.3	2.0	11	12	12	16	1.3	.96	8
	3057	6.2	2.9	2.1	2.7	2.1	1.6	10	12	12	15	1.3	.78	9
	4290	5.4	2.9	2.1	2.9	1.9	1.7	10	11	12	16	1.4	.94	9
	4294	5.8	3.0	2.0	2.9	1.9	1.6	11	12	12	16	1.2	.96	8
	4307	6.1	3.0	2.1	2.9	2.0	1.7	10	12	12	15	1.5	1.0	8
	4310	5.2	3.0	2.0	2.6	2.0	1.7	9	11	12	15	1.4	.97	8
	4314	5.3	2.9	2.0	2.8	2.3	1.8	11	12	12	16	1.4	.94	8
	1638	5.0	2.9	2.0	2.6	1.8	2.0	10	11	12	15	1.3	.91	9
	1645	5.2	2.8	2.1	2.9	2.1	1.8	11	12	12	16	1.4	.92	9
	2792	5.2	2.9	2.0	2.9	2.4	1.8	11	13	11	16	1.3	.85	9
	3525	5.0	3.1	2.1	2.9	2.3	2.0	10	11	11	15	1.3	.91	9
	3556	4.6	3.0	2.1	2.8	2.0	1.7	10	11	11	14	1.6	.92	9
	3558	5.2	2.9	2.1	2.7	1.9	1.8	11	12	12	15	1.2	.82	9
	3607	6.0	2.9	2.1	2.7	2.1	1.5	10	10	11	16	1.5	1.1	8
	3724	5.0	2.9	2.0	2.7	2.0	1.7	11	12	12	16	1.3	.96	8
	4585	6.2	3.0	2.1	2.7	2.0	1.8	10	12	12	16	1.3	.95	8
Under 200 millimeters	3102	5.1	2.8	1.9	2.6	2.0	1.6	9	10	11	16	1.6	.84	8
	3228	5.1	2.7	1.9	2.6	1.6	1.5	9	11	12	16	1.7	1.1	7
	3236	5.0	2.8	2.0	2.7	1.8	1.5	11	13	12	16	1.3	.79	8
	3252	5.0	2.7	1.9	2.6	1.8	1.6	10	11	10	15	1.5	.91	9
	59590	5.5	3.0	2.0	2.6	2.1	1.6	10	11	12	17	1.3	.93	8
	59592	5.2	3.0	2.0	2.7	2.0	1.7	10	11	12	15	1.6	1.0	8
	59612	5.4	3.0	2.1	2.8	2.0	1.7	9	11	11	16	1.7	1.0	9
	59614	5.1	2.8	2.1	2.7	2.0	1.6	10	11	11	16	1.4	.98	8
	59617	6.1	3.1	2.1	2.8	1.9	1.5	9	11	12	16	1.6	.97	8
	59690	4.5	2.7	1.9	2.7	2.0	1.5	10	12	12	16	1.5	1.0	8

TABLE 70.—*Records of the occurrence of Leucichthys artedi in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, the abundance of the species in the lift, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Abundance	Preserved specimens examined: +225 mm.	Preserved specimens examined: −225 mm.
Lake Huron proper:								
St. Ignace, Mich.	1	July 17, 1917	Off the city	(1)	4	Occasional	8	3
Cheboygan, Mich.	2	Sept. 29, 1917	Point Au Sable	(1)	3½	(2)	6	1
Rogers, Mich.	3	Oct. 14, 1917	12 miles E. by N. ½ N. of city	2¾	35	Only specimens taken in lift.	2	------
Alpena, Mich.	4	Aug. 13, 1917	Sulphur Island	(1)	4	Occasional	11	------
	5	Sept. 5, 1917	Misery Bay	2¾	3	Rare	1	------
	6	Sept. 8, 1917	22 miles SE. by E. ½ E. of can buoy.	1½	30	do	------	9
	7	Sept. 10, 1917	8 miles E. by N. of can buoy	4½	20	Only specimens taken in lift.	1	2
	8	do	13½ miles SE. by S. of can buoy	4½	15	do	3	9
	9	Sept. 12, 1917	11 miles SE. ¾ E. of can buoy	4½	15–17	do	------	1
	10	Sept. 14, 1917	24 miles SE. by E. ½ E. of can buoy.	4½	24	Rare	1	5
	11	Sept. 17, 1917	13½ miles SE. by S. of can buoy	4½	15	do	------	2
	12	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy.	4½	17	do	------	3
	13	Sept. 26, 1917	13 miles SE. by S. of can buoy	4½	17	Only specimens taken in lift.	4	2
	14	Sept. 24, 1917	Can buoy to Sulphur Island	2¾	8–10	Common	1	3
	15	Sept. 27, 1917	do	2¾	8–10	do	------	------
	16	Nov. 2, 1917	7 miles ENE. of can buoy	2¾	15	Occasional	------	------
	17	Nov. 15, 1919	------	2¾	15	do	18	------
East Tawas, Mich.	18	Oct. 22, 1917	Off the city	(1)	4–8	Common	21	6
Bay City, Mich.	19	Oct. 25, 1917	Off Point Au Gres	(1)	4–8	do	25	1
	20	Nov. —, 1922	Saginaw Bay at Tobico	(1)	3	do	18	7
Harbor Beach, Mich.	21	Dec. 9, 1917	------	------	------	(2)	2	9
	22	Mar. 15, 1919	------	1½	31	Rare	------	1
Duck Islands, Ontario.	23	Oct. 18, 1919	Off Islands	4½	5–10	Occasional	10	2
Tobermory, Ontario	24	Oct. 2, 1919	Off Plucky Island	4½	18–20	do	------	3

[1] Pound net.

[2] Lift not examined or percentage not ascertained.

TABLE 70.—*Records of the occurrence of Leucichthys artedi in Lake Huron*—Continued

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Abundance	Preserved specimens examined: +225 mm.	Preserved specimens examined: −225 mm.
North Channel:								
Blind River, Ontario	25	Oct. 6, 1917	Off Grant Island	4½	3–5	Occasional		
	26	Nov. 8, 1917	Off the city	(1)	4	Common	6	
Cutler, Ontario	27	Nov. 11, 1917	Cutler Bay	3		do	20	
Gore Bay, Ontario	28	Nov. 10, 1917	Off Barrie Island	(1)	5	do	2	
Kagawong, Ontario	29	do	Off Clapperton Island	(1)	6	do	3	
	30	Oct. 16, 1919	do	(1)	6	do	1	
Georgian Bay:								
Wiarton, Ontario	31	Nov. 5, 1917	Colpoys Bay	(1)	4	do	2	13
	32	July 29, 1919	do	(1)	4	Occasional		6
	33	Dec. 3, 1919	do	1½	15	do	1	14
Killarney, Ontario	34	Oct. 12, 1919	Off the city	(1)	10–12	Common	26	15
Borrowed specimens:								
Georgian Bay [3]							16	9
Bayport, Mich.[4]							1	1
Port Huron, Mich.[4]							2	
Blind River, Ontario [4]							2	1
Collingwood, Ontario[4]							1	

[1] Pound net. [3] Donated by Dr. B. A. Bensley. [4] U. S. National Museum collection.

TABLE 71.—*Numerical expressions of certain systematic characters for 10 specimens of the manitoulinus form of Leucichthys artedi, 40 specimens of the artedi form of that species, 30 over 200 millimeters long and for 10 under 200 millimeters long, all from various parts of Lake Huron, selected according to size and locality*

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA
+200 millimeters:											
Manitoulinus form	1114	Cutler, Ontario	240	♂	17+29	69	4.3	6.3	8.5	10.0	2.4
	1118	do	248	♂	15+28	74	4.1	5.9	7.8	8.8	2.7
	1119	do	274	♀	15+29	76	4.2	5.9	9.2	9.4	2.7
	1120	do	257	♂	15+30	77	4.0	6.4	8.8	8.5	2.6
	1121	do	237	♂	17+30	72	4.0	5.7	8.7	9.0	2.8
	1123	do	286	♂	16+30	71	4.2	6.2	7.6	8.2	2.6
	1125	do	231	♂	16+30	70	4.0	6.0	7.4	8.5	2.5
	1127	do	268	♂	17+30	71	4.1	5.8	7.6	7.8	2.4
	1130	do	257	♂	18+29	73	4.0	5.6	8.3	8.1	2.6
	1131	do	268	♂	16+30	76	4.0	5.7	7.0	7.3	2.5
Artedi form—											
Open lake	13	St. Ignace, Mich	224	♀	18+31	80	4.2	6.0	10.1	9.7	2.7
	16	do	295	♀	18+31	90	4.7	6.8	10.4	10.5	2.7
	2515	Duck Islands, Ontario	250	♂	18+31	81	4.4	6.1	9.8	12.0	2.8
	2531	do	291	♀	19+31	78	4.4	6.2	9.7	9.3	2.6
	829	Cheboygan, Mich	305	♂	17+29	83	4.5	6.2	8.8	8.8	2.7
	834	do	281	♀	17+31	82	4.4	6.7	9.8	10.3	2.8
	196	Alpena, Mich	257	♀	18+32	83	4.7	6.8	9.9	10.5	2.7
	208	do	245	♂	16+29	82	4.4	6.3	10.2	9.4	2.8
	211	do	253	♂	17+31	80	4.4	6.2	11.5	10.4	3.0
	220	do	245	♀	17+31	84	4.3	6.0	9.6	9.9	2.7
Saginaw Bay	979	East Tawas, Mich	266	♀	16+28	87	4.5	6.6	11.5	10.6	2.7
	982	do	228	♀	18+33	79	4.5	6.5	8.0	9.3	2.5
	1024	Bay City, Mich	324	♂	18+30	81	4.8	6.9	9.9	10.9	2.6
	1035	do	283	♂	18+27	81	4.6	6.7	10.9	9.7	2.7
	1044	do	265	♂	18+32	82	4.5	6.4	10.3	8.9	2.6
	1045	do	296	♀	17+28	84	4.1	6.8	10.5	9.7	2.7
	1046	do	264	♂	16+31	81	4.7	6.9	9.7	10.2	2.5
	1050	do	348	♂	17+28	82	4.9	7.3	11.2	10.0	2.8
	1053	do	276	♂	18+29	75	4.7	6.5	10.6	10.3	2.6
	1054	do	270	♂	18+31	81	4.5	6.8	10.0	9.9	2.6
North Channel and Georgian Bay.	1083	Blind River, Ontario	258	♀	15+32	87	4.3	6.0	10.7	9.8	2.7
	1089	do	270	♀	18+32	83	4.5	6.3	9.9	9.6	2.8
	1109	Gore Bay, Ontario	291	♀	16+27	85	4.5	6.3	9.3	9.7	2.7
	1097	Kagawong, Ontario	290	♀	18+32	78	4.2	6.2	9.2	9.0	2.8
	1100	do	285	♀	16+29	81	4.3	6.3	8.8	8.6	2.8
	2436	Killarney, Ontario	262	♀	16+29	78	4.4	6.1	10.4	10.8	2.7
	2539	do	325	♂	15+30	83	4.4	6.3	9.5	9.3	2.8
	2547	do	272	♂	15+28	83	4.4	6.3	10.4	10.2	2.8
	1068	Wiarton, Ontario	242	♀	16+30	80	4.4	6.5	10.0	10.3	2.7
	1073	do	281	♂	17+27	89	4.4	6.3	9.8	10.2	2.6

TABLE 71.—*Numerical expressions of certain systematic characters for 10 specimens of the manitoulinus form of Leucichthys artedi, 40 specimens of the artedi form of that species, 30 over 200 millimeters long and for 10 under 200 millimeters long, all from various parts of Lake Huron, selected according to size and locality*—Continued

Size	Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA
−200 millimeters	210	Alpena, Mich.	161	Im. ♂	18+32	79	4.6	6.1	11.5	10.3	2.7
	218	do	172	♀	16+33	83	4.5	6.1	9.5	9.5	2.7
	232	do	180	Im. ♀	16+28	79	4.3	5.8	9.5	10.0	2.7
	250	do	166	Im. ♀	16+30	87	4.6	6.3	11.4	11.0	2.7
	271	do	173	♂	18+31	83	4.4	5.9	10.8	9.7	2.8
	272	do	197	♀	17+29	80	4.5	6.3	9.8	9.7	2.7
	703	do	171	♀	17+31	78	4.1	5.7	10.1	10.0	2.9
	722	do	171	♀	16+30	83	4.2	5.8	9.9	9.2	2.9
	2582	Wiarton, Ontario	180	♂	18+29	81	4.1	5.6	10.5	9.0	2.7
	2616	do	178	♂	16+32	81	4.4	6.1	10.0	8.9	2.9

Size	Field No.	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
+200 millimeters: Manitoulinus form	1114	7.9	3.8	7.5	1.9	2.1	3.0	3.3	4.9	3.7	2.7	3.9	2.0	3.4
	1118	8.2	3.6	6.7	1.8	2.1	3.0	3.2	4.7	3.7	2.7	4.2	2.1	4.2
	1119	9.0	3.4	7.2	2.1	2.1	3.0	3.3	4.7	3.7	2.8	4.0	1.9	4.3
	1120	9.0	4.0	7.4	1.8	2.1	3.3	3.4	4.9	3.4	2.7	4.0	1.9	3.9
	1121	8.2	3.4	7.7	2.2	2.0	2.9	3.2	4.6	3.7	2.6	4.0	2.1	3.4
	1123	9.2	3.7	7.1	1.9	2.0	3.0	3.2	4.8	3.7	2.8	3.8	2.0	4.1
	1125	8.0	3.6	7.2	1.9	2.0	2.9	3.1	4.7	3.8	2.6	4.0	2.0	3.8
	1127	11.1	3.5	7.0	1.9	2.1	2.9	3.0	4.2	3.8	2.6	3.8	2.0	3.2
	1130	9.1	3.6	7.1	1.9	2.0	2.9	3.2	4.4	3.6	2.8	3.7	1.9	4.5
	1131	8.1	3.7	7.8	1.8	1.9	2.8	3.0	4.4	3.7	2.5	3.7	1.9	3.6
Artedi form—Open lake	13	8.5	4.6	7.9	1.6	2.1	3.1	3.3	4.8	3.8	2.9	3.8	2.1	4.5
	16	8.5	4.7	7.9	1.6	2.2	3.2	3.6	5.3	4.0	2.8	3.9	2.0	3.6
	2515	8.3	4.6	8.5	1.8	2.1	3.0	3.4	4.9	3.8	3.0	4.1	2.1	3.6
	2531	9.0	4.1	7.1	1.7	2.1	3.0	3.4	4.9	3.9	3.1	3.8	2.1	3.8
	829	8.6	4.3	7.3	1.6	2.2	3.0	3.5	4.8	4.1	2.8	3.9	2.1	3.9
	834	7.9	5.1	8.3	1.6	2.2	3.3	3.5	5.1	4.3	3.0	4.0	2.2	3.7
	196	8.5	4.5	7.6	1.7	2.2	3.2	3.7	5.3	3.8	2.8	3.8	2.0	4.0
	208	9.4	4.1	8.1	1.9	2.2	3.1	3.4	4.9	3.9	2.8	3.9	2.0	4.2
	211	8.4	4.2	7.4	1.7	2.1	3.1	3.5	5.1	3.9	2.8	3.9	2.0	4.0
	220	8.5	4.2	8.1	1.9	2.1	3.0	3.2	4.5	4.0	2.8	3.9	2.1	3.8
Saginaw Bay	979	8.3	5.4	9.8	1.8	2.2	3.3	3.5	5.1	4.4	3.0	4.0	2.1	3.1
	982	8.7	3.8	6.9	1.7	2.2	3.2	3.6	5.1	4.3	2.8	4.1	2.1	3.3
	1024	8.7	4.2	7.1	1.6	2.3	3.4	3.7	5.3	4.4	3.2	4.3	2.2	3.2
	1035	7.5	4.7	7.8	1.6	2.2	3.2	3.6	5.2	4.3	3.2	4.2	2.3	3.8
	1044	9.4	4.4	8.2	1.8	2.2	3.2	3.4	4.9	4.4	3.2	3.8	2.0	4.6
	1045	8.5	3.9	6.5	1.6	2.3	3.3	3.7	5.3	4.7	2.9	4.0	2.2	4.4
	1046	8.1	4.5	9.0	1.9	2.2	3.3	3.6	5.3	4.2	3.0	4.1	2.1	3.5
	1050	6.9	4.5	8.4	1.8	2.3	3.5	3.7	5.6	4.4	3.0	4.0	2.3	3.3
	1053	7.7	4.1	8.0	1.9	2.2	3.1	3.6	5.0	4.4	2.9	4.0	2.2	3.2
	1054	8.5	4.3	7.4	1.6	2.2	3.3	3.5	5.2	4.4	2.9	3.9	2.1	4.1
North Channel and Georgian Bay.	1083	9.1	4.3	7.5	1.7	2.1	2.9	3.4	4.6	3.9	2.7	3.8	1.9	3.9
	1089	8.9	4.2	7.9	1.8	2.1	3.0	3.4	4.9	4.0	2.8	4.0	2.0	4.4
	1109	8.8	4.4	8.5	1.8	2.2	3.1	3.4	4.8	3.8	2.8	3.8	2.0	4.0
	1097	7.7	3.7	8.7	2.3	2.1	3.1	3.2	4.8	4.0	3.0	4.1	2.1	3.6
	1100	8.9	4.5	8.3	1.7	2.0	3.0	3.3	4.9	3.8	2.9	4.0	2.0	3.7
	2436	8.5	4.3	7.7	1.7	2.2	3.0	3.4	4.7	4.1	2.7	3.9	2.0	3.9
	2539	8.2	4.1	7.0	1.7	2.1	3.0	3.5	4.9	4.5	3.1	3.9	2.2	4.0
	2547	9.0	4.3	7.2	1.6	2.2	3.2	3.5	5.0	4.2	2.9	4.0	2.1	5.0
	1068	9.2	4.3	8.9	2.0	2.2	3.2	3.4	5.0	3.9	3.0	4.1	2.1	4.5
	1073	9.0	4.3	8.5	1.9	2.1	3.0	3.4	4.9	3.9	2.8	3.9	2.0	5.0
−200 millimeters	210	7.0	4.9	8.4	1.7	2.2	3.0	3.4	4.6	3.8	2.9	3.7	2.0	4.0
	218	7.8	4.7	7.2	1.6	2.2	3.0	3.3	4.6	4.0	2.7	3.5	2.0	3.5
	232	8.5	4.3	7.8	1.7	2.0	2.8	3.2	4.3	3.9	2.7	3.7	1.9	4.0
	250	7.5	4.4	8.7	1.8	2.1	3.0	3.1	4.8	3.9	3.0	3.6	2.1	3.9
	271	7.5	4.6	8.6	1.8	2.1	2.8	3.4	4.5	3.9	2.6	3.6	1.9	3.7
	272	8.3	5.3	9.3	1.7	2.2	3.1	3.4	4.8	4.3	2.6	3.9	2.0	4.0
	703	8.0	4.6	8.5	1.8	2.0	2.8	3.2	4.4	3.9	2.6	3.7	2.0	4.1
	722	8.1	4.5	7.7	1.7	2.1	2.9	3.3	4.5	3.7	2.8	4.0	2.0	3.7
	2582	9.4	4.2	8.7	2.0	2.1	2.9	3.2	4.4	3.9	2.7	3.6	2.0	3.7
	2616	7.1	4.8	8.9	1.8	2.1	2.8	3.2	4.3	4.0	2.6	3.7	2.0	3.3

TABLE 71.—*Numerical expressions of certain systematic characters for 10 specimens of the manitoulinus form of Leucichthys artedi, 40 specimens of the artedi form of that species, 30 over 200 millimeters long and for 10 under 200 millimeters long, all from various parts of Lake Huron, selected according to size and locality*—Continued

Size	Field No.	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
+200 millimeters: Manitoulinus form	1114	6.7	2.5	1.9	2.7	1.7	1.5	10	12	11	16	1.1	1.1	8
	1118	6.0	2.5	1.8	2.9	1.8	1.4	11	12	11	16	1.4	1.0	8
	1119	6.3	2.6	2.0	2.8	1.7	1.6	10	12	11	16	1.6	1.0	9
	1120	5.9	2.3	1.8	2.7	1.7	1.6	11	12	11	15	1.5	.98	8
	1121	5.8	2.6	1.8	2.8	1.7	1.4	10	11	12	16	1.6	1.0	9
	1123	6.0	2.5	1.8	2.6	1.6	1.5	11	12	11	16	1.3	.97	9
	1125	5.5	2.5	1.8	2.6	1.6	1.4	10	12	12	15	1.5	1.0	9
	1127	5.8	2.7	1.9	2.7	1.6	1.1	10	12	11	16	1.5	1.0	9
	1130	6.1	2.6	2.0	2.7	1.7	1.3	10	12	12	15	1.5	.98	8
	1131	5.3	2.6	1.8	2.6	1.6	1.3	11	13	12	14	1.3	.94	9
Artedi form— Open lake	13	6.3	2.7	2.0	2.7	2.0	1.6	11	12	11	16	1.5	1.0	9
	16	5.9	2.8	2.0	2.6	2.2	1.7	10	12	12	17	1.3	.99	9
	2515	5.6	2.7	2.1	2.9	2.0	1.8	10	11	12	17	1.3	1.3	8
	2531	5.3	2.8	2.2	2.7	2.4	1.7	11	12	13	17	1.2	.83	8
	829	6.1	3.0	2.0	2.8	2.0	1.7	11	12	11	17	1.2	.87	8
	834	7.1	3.0	2.0	2.7	2.5	2.0	11	11	11	16	1.1	.83	9
	196	5.8	2.6	1.9	2.6	2.2	1.7	11	11	11	16	1.4	.99	8
	208	5.2	2.7	1.9	2.7	1.9	1.6	9	11	11	16	1.5	1.0	8
	211	5.4	2.6	1.9	2.6	2.1	1.8	10	11	11	16	1.6	1.0	8
	220	5.0	2.8	2.0	2.6	1.7	1.4	10	11	12	15	1.5	1.0	8
Saginaw Bay	979	5.2	3.0	2.0	2.7	2.3	1.8	9	12	11	15	1.4	.88	8
	982	6.2	3.0	2.0	2.9	2.0	1.8	10	11	11	17	1.2	1.0	9
	1024	6.0	3.1	2.2	3.0	2.0	1.9	10	11	11	15	1.2	.96	8
	1035	5.3	3.0	2.2	2.8	2.2	1.9	10	11	11	15	1.3	.90	8
	1044	5.6	3.1	2.2	2.7	2.2	1.7	10	------	12	15	1.3	.84	9
	1045	6.5	3.3	2.0	2.8	2.5	1.8	10	11	11	15	1.3	.85	9
	1046	5.4	2.9	2.1	2.8	2.2	1.8	11	11	11	14	1.2	.87	9
	1050	5.8	2.9	2.0	2.7	2.3	1.8	10	12	11	16	1.3	.89	8
	1053	5.8	3.2	2.1	2.8	------	1.8	9	11	11	16	1.5	.94	8
	1054	6.5	3.0	1.9	2.6	2.3	1.8	10	11	11	15	1.4	.90	8
North Channel and Georgian Bay.	1083	5.9	2.8	2.0	2.7	2.2	1.4	10	12	12	16	1.4	.88	8
	1089	7.0	2.8	2.0	2.8	2.1	1.7	10	12	11	17	1.3	.91	9
	1109	5.9	2.7	2.0	2.7	2.2	1.8	11	12	12	16	1.2	.94	9
	1097	5.9	2.7	2.1	2.8	1.9	1.6	10	13	12	16	1.4	1.0	8
	1100	5.9	2.6	2.0	2.8	2.0	1.7	10	12	11	15	1.3	.84	9
	2436	5.1	3.0	1.9	2.8	2.3	1.7	9	11	12	16	1.3	.99	9
	2539	6.1	3.2	2.2	2.7	2.5	2.0	10	10	11	15	1.1	.91	8
	2547	6.6	2.9	2.0	2.8	2.3	1.8	10	11	11	15	1.2	1.1	8
	1068	5.4	2.6	2.0	2.8	2.1	1.8	10	11	11	16	1.4	.90	8
	1073	5.2	2.7	2.0	2.7	2.0	1.8	11	12	12	17	1.3	.92	8
−200 millimeters	210	5.7	2.8	2.1	2.8	2.0	1.8	10	11	12	16	1.6	.96	8
	218	4.8	2.9	2.0	2.5	2.0	1.7	10	12	11	16	1.5	.95	8
	232	5.2	2.9	2.0	2.8	1.9	1.6	10	11	11	16	1.4	.94	9
	250	6.0	2.8	2.1	2.6	2.1	1.9	10	11	11	16	1.5	.93	8
	271	4.9	2.9	2.0	2.6	2.2	1.7	9	12	11	16	1.4	.84	9
	272	5.3	3.0	1.8	2.7	2.0	1.6	10	12	11	16	1.4	.89	8
	703	5.1	2.8	1.9	2.7	1.8	1.7	9	11	11	17	1.5	.97	9
	722	5.0	2.6	2.0	2.9	2.1	1.7	10	12	11	17	1.4	.87	8
	2582	4.5	2.9	2.0	2.7	2.0	1.5	10	12	11	16	1.5	.93	9
	2616	5.5	2.9	1.9	2.6	2.1	1.6	11	13	11	16	1.4	.87	9

TABLE 72.—*Characteristics of certain herring that are intermediate between the artedi and manitoulinus forms*

Field No.	Locality	Scales	L/H	H/E	Pv/P	L/D	H/M	Color
1085	Blind River	74 (M)	4.5 (A)	3.9 (A)	1.8 (M)	3.6 (M)	3.0 (A)	Pale (A).
1086	do	72 (M)	4.1 (M)	4.1 (A)	1.8 (M)	3.7 (M)	2.8 (A)	Do.
1090	do	83 (A)	4.2 (M)	4.1 (A)	2.0 (A)	4.0 (A)	2.9 (A)	Do.
1091	do	85 (A)	4.3 (A)	3.9 (A)	2.0 (A)	4.4 (A)	3.0 (A)	Dark (M).
1097	Kagawong	78 (A)	4.2 (M)	4.0 (A)	1.9 (A)	3.7 (M)	3.0 (A)	Pale (A).

TABLE 73.—*Records of the occurrence of Leucichthys artedi in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, the abundance of this species in the lift, and the number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Abundance	Preserved specimens examined	
								+225 mm.	−225 mm.
Sault Ste. Marie, Mich.	1	June 14, 1922	10 miles NW. by W. ¼ W. of Point Iroquois Light.	2½, 2¾	38		Rare	2	
Grand Marais, Mich.	2	Oct. 3, 1917	In the harbor					4	
Marquette, Mich.	3	Feb. 8, 1921		1½	10–11			4	11
	4	Aug. 5, 1921	31 miles N. ¾ E.	2¾, 4½	100		Rare	4	
	5	Aug. 9, 1921	Marquette Bay	[1]	5	Sand	Occasional	3	11
	6	Aug. 11, 1921	18 miles NE. by N.	2½, 2¾	100–80		Rare	2	1
	7	Nov. —, 1925						5	
Ontonagon, Mich.	8	Aug. 16, 1921	54 miles W. by N.	4½	25–80			1	
	9	Aug. 24, 1921	21 miles west	2½, 2¾	15–45	Red clay	Rare	3	
	10	Aug. 25, 1921	6 miles NNW.	2½, 2¾	20–38	Sand-clay	do.	8	
Apostle Islands, Wis.	11	July 11, 1922	Between Cat and South Twin Islands.	2½, 2¾	15–20	Sand	do.	1	
Duluth, Minn.	12	July 17, 1922	20 miles NE. by E.	2⅝	30–40	do.		2	
Grand Marais, Minn.	13	July 18, 1922	In Grand Marais Harbor.	[2]	1			300	
	14	July 17, 1922	At mouth of Devils Track River.	[2]	1			300	
Port Arthur, Ontario.	15	July 20, 1922	Off Demers Point	[1]	8	Mud	Occasional	8	4
	16	Nov. 25, 1922	Thunder Bay, between Pie and Welcome Islands.	2½			Abundant	12	
	17	Sept. 15, 1923	North of Silver Island	2½	14	Mud		5	
	18	do.	Thunder Bay, off Thunder Cape.	2½	31	Grayish-brown clay.	Rare		1
	19	Sept. 17, 1923	Thunder Bay, inside Welcome Islands.	2½	11	do.	do.	2	
	20	Sept. 19, 1923	Thunder Bay, off Sawyer Bay.	2½	49	do.	do.	3	1
Rossport, Ontario	21	Oct. 1, 1921	Off the town	2¾	6		Occasional	6	
	22	Oct. 4, 1921	Off Bread Rock	2½, 2¾	80–90	Grayish-brown clay.	Rare	1	
	23	Mar. 10, 1922		2½			Common	44	18
	24	Aug. 10, 1922	Moffat Strait	[1]	4			11	8
	25	do.	Off Armour Point	[1]	4			5	7
	26	Sept. 25, 1923	Moffat Strait	2½	13–14	Clay-sand		6	1
Michipicoten Island, Ontario.	27	June 19, 1922	6 miles northeast of East-End Light.	4½	15–35			4	
Coppermine Point, Ontario.	28	June 26, 1922	Off Alona Bay	2½, 2¾	60			7	
Batchawanna, Ontario.	29	June 17, 1922	Batchawanna Bay	[1]	3–13	Clay-sand		7	8
Borrowed specimens:									
Marquette, Mich.[3]								22	
Duluth, Minn.[4]								2	
Marquette, Mich.[5]								1	
Knife River, Minn.[5]									1
Duluth, Minn.[5]								4	
Port Arthur, Ontario.[5]								1	

[1] Pound net.
[2] Seine.
[3] Field Museum collection.
[4] University of Toronto collection.
[5] U. S. National Museum collection.

TABLE 74.—*Numerical expression of certain systematic characters for 20 specimens of Leucichthys artedi from Lake Superior, 10 of them over 200 millimeters long and 10 under 200 millimeters, selected according to size and locality*

Size	Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA
Albus form, over 200 millimeters.	015	Silver Island, Ontario	236	18+30	♀	80	4.1	5.9	9.6	9.7	2.5
	57379	Black Bay	262	18+30	♀	75	4.4	6.2	8.4	8.1	2.7
	0282	Moffat Strait	240	20+33	♀	83	4.4	6.1	9.6	10.3	2.7
	0287	do	232	18+32	♀	77	4.4	6.1	8.6	8.5	2.7
Artedi form:											
Over 200 millimeters	53852	Rossport, Ontario	314	18+29	♀	86	4.6	6.2	10.4	9.8	2.7
	57115	Alona Bay	270	17+28	♀	92	4.6	6.4	10.5	10.8	2.5
	57133	do	272	16+29	♂	94	4.6	6.4	11.3	9.3	2.7
	57846	Batchawanna, Ontario	258	16+31	♂	89	4.5	6.1	8.8	9.2	2.6
	57851	do	238	16+28	♂	82	4.3	5.9	9.3	9.5	2.7
	53739	Ontonagon, Mich	280	17+30	♀	90	4.5	6.2	11.2	11.5	2.8
Under 200 millimeters	53054	Marquette, Mich	190	18+30	Im. ♂	83	4.6	6.3	11.0	9.9	2.8
	53056	do	192	18+30	Im. ♀	90	4.6	6.6	12.6	10.1	2.7
	53060	do	176	17+29	Im. ♀	84	4.4	6.0	10.3	10.3	2.7
	53061	do	174	17+29	Im. ♂	89	4.5	6.2	10.1	8.7	2.6
	53508	do	195	17+30	Im. ♀	87	4.5	6.0	10.0	9.7	2.6
	53531	do	193	16+28	♂	84	4.4	6.2	9.2	9.4	2.7
	57199	Black Bay	140	18+32	Im. ♂	87	4.3	6.0	10.6	9.8	2.6
	57354	do	143	16+29	Im. ♂	78	4.2	5.7	9.5	9.3	2.6
	57355	do	173	18+30	Im. ♀	90	4.3	5.7	10.2	9.0	2.7
	57356	do	153	16+27	Im. ♂	72	4.2	5.7	9.6	10.2	2.7

Size	Field No.	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H	SA/O	H/E	H/M	H/S	H/J	H/Ad
Albus form, over 200 millimeters	015	8.7	4.0	8.4	2.0	2.0	2 9	3.2	4.6	3.8	3.0	4.3	2.1	4.0
	57379	9.7	3.9	7.9	2.0	2.1	2.9	3.4	4.7	3.9	2.9	3.7	2.1	3.4
	0282	7.5	4.0	8.0	2.0	2.1	2.9	3.4	4.8	3.6	2.7	3.8	1.9	3.6
	0287	9.2	3.8	9.2	2.3	2.2	3.0	3.4	4.7	3.8	2.8	3.9	2.0	3.7
Artedi form:														
Over 200 millimeters	53852	7.8	4.6	8.0	1.7	2.2	3.1	3.6	4.9	4.5	2.9	3.7	2.0	4.2
	57115	7.9	4.9	10.0	2.0	2.2	3.0	3.5	4.8	4.4	2.9	3.6	1.8	3.8
	57133	8.5	4.7	8.2	1.7	2.2	3.2	3.4	4.8	4.5	2.9	3.8	2.1	4.4
	57846	8.1	4.6	9.5	2.0	2.1	2.9	3.4	4.6	4.3	3.0	3.5	2.0	3.5
	57851	8.6	4.7	9.5	2.0	2.1	2.9	3.2	4.5	4.2	2.8	3.6	2.0	4.2
	53739	7.5	4.9	9.6	1.9	2.2	3.0	3.5	4.9	4.4	2.8	3.4	2.1	4.4
Under 200 millimeters	53054	8.6	5.0	8.2	1.6	2.1	2.9	3.4	4.7	4.1	2.9	4.0	1.9	3.6
	53056	8.0	4.8	8.3	1.7	2.2	3.2	3.4	4.9	4.1	2.9	4.1	2.0	3.6
	53060	7.6	4.6	8.8	1.9	2.0	2.8	3.3	4.5	4.2	2.8	3.9	2.0	3.3
	53061	8.7	5.1	8.2	1.5	2.2	3.1	3.4	4.8	4.0	2.9	3.7	2.1	4.1
	53508	7.9	4.7	8.8	1.8	2.1	2.8	3.4	4.6	4.0	2.8	3.9	2.0	4.1
	53531	7.7	4.5	8.7	1.9	2.1	3.0	3.4	4.7	3.9	2.7	3.9	2.0	3.6
	57199	7.7	5.0	9.3	1.8	2.1	2.9	3.2	4.5	4.0	2.7	3.6	2.0	4.2
	57354	7.5	4.6	10.2	2.1	2.0	2.7	3.2	4.3	3.4	2.6	3.7	1.9	3.7
	57355	7.5	4.9	9.1	1.8	2.1	2.9	3.3	4.4	4.0	2.7	3.5	1.9	3.9
	57356	7.6	4.7	9.5	1.6	2.1	2.9	3.2	4.4	3.7	2.7	4.0	2.0	3.6

Size	Field No.	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Albus form, over 200 millimeters	015	5.4	2.7	2.0	3.0	1.8	1.6	11	11	12	16	1.5	1.0	8
	57379	5.2	2.8	2.1	2.8	2.0	1.6	11	12	12	15	1.3	.86	8
	0282	5.2	2.6	1.9	2.9	2.0	1.6	10	11	11	18	1.4	.95	8
	0287	5.2	2.4	2.0	2.8	1.9	1.6	11	13	11	15	1.2	.84	8
Artedi form:														
Over 200 millimeters	53852	5.5	3.3	2.1	2.7	2.2	1.8	10	12	12	17	1.4	.87	9
	57115	5.3	3.2	2.1	2.6	2.2	1.7	10	11	11	16	1.5	1.0	8
	57133	5.7	3.2	2.1	2.7	2.3	1.8	10	13	12	17	1.4	.83	8
	57846	5.5	3.3	2.2	2.6	2.1	1.7	11	13	11	17	1.3	.85	8
	57851	5.0	3.0	2.0	2.6	2.1	1.7	11	12	11	16	1.3	.92	8
	53739	5.6	3.1	2.0	2.4	2.2	1.9	10	10	11	17	1.5	.98	9
Under 200 millimeters	53054	5.1	3.0	2.1	2.9	2.0	1.7	11	11	12	18	1.5	.87	8
	53056	5.1	2.9	2.0	2.9	2.1	1.7	10	12	12	17	1.7	.84	8
	53060	5.0	3.0	2.0	2.8	1.9	1.7	10	12	11	18	1.5	.94	8
	53061	6.1	2.8	2.0	2.6	2.1	1.7	10	13	11	17	1.5	.87	8
	53508	5.3	3.0	2.1	2.9	2.0	1.8	11	12	12	18	1.4	.89	8
	53531	4.7	2.8	2.0	2.8	1.9	1.6	11	12	11	16	1.3	.93	8
	57199	5.3	2.8	1.9	2.6	1.8	1.5	10	12	12	18	1.5	.97	8
	57354	5.4	2.5	1.9	2.7	1.6	1.4	11	12	12	16	1.5	.88	9
	57355	4.7	3.0	2.0	2.6	1.9	1.6	10	13	12	17	1.5	------	9
	57356	5.0	2.7	2.0	2.9	1.8	1.6	10	11	11	17	1.5	1.0	8

TABLE 75.—*Records of the occurrence of Leucichthys artedi in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.[1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined	
					+225 mm.	−225 mm.
1	July 28, 1922	Off Macdiarmid	2½, 2¾	30	1	
2	Sept. 8, 1923	do		6		2
3	Sept. 11, 1925	do		5		5
4	July 30, 1922	Off Blackwater River		1		1
5	Sept. 6, 1923	Off Selwyn Island		?		3
6	Aug. 9, 1922	Humboldt Bay		5		5
7	Sept. 3, 1923	do		1–6		3
8	Sept. 5, 1923	Off McKellar Island				1
9	Aug. 10, 1922	Ombabika Bay		5		16
10	Aug. 21, 1923	do		1		15
11	July 26, 1923	Windigo Bay		3		3
12	Sept. 5, 1925	Off Shakespeare Island		1		2
13	Aug. 25, 1921	Off source of Nipigon River		10		1
14	July 26, 1922	do	2½, 2¾	10-15	8	7
15	Aug. 2, 1922	do		15		1
16	Aug. 28, 1923	Off Virgin Island		10-15		1
17	Aug. 30, 1923	do		18		1
18	Aug. 27, 1921	Sandy Bay		5		3
19	July 16, 1923	do		1		2
20	Sept. 6, 1923	do		7		2
21	Oct. 26, 1922	Unknown	4½		1	1

[1] All records except 1, 4, 14, and 21 are from University of Toronto collections.

TABLE 76.—*Numerical expressions of certain systematic characters for 10 specimens of Leucichthys artedi from Lake Nipigon, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
57202	Off source of Nipigon River	220	19+32	♂	73	4.2	6.1	8.2	8.8	2.8	8.5	4.2	9.5	2.2	2.0	3.0	3.3
57205	do	237	18+29	♂	74	4.1	5.9	9.1	9.1	2.9	8.3	4.3	9.8	2.2	2.0	2.8	3.1
57207	do	222	16+31	♂	71	4.2	6.0	8.8	7.7	2.7	7.9	4.2	9.2	2.1	2.0	2.9	3.2
57209	do	224	18+31	♂	76	4.1	5.7	9.4	9.3	2.7	8.6	4.1	9.7	2.3	2.0	2.8	3.3
57218	do	224	18+32	♀	74	4.3	5.7	8.9	8.6	2.6	7.2	4.1	8.9	2.1	2.0	2.7	3.3
57220	do	225	18+34	♀	74	4.0	5.6	9.6	9.0	3.0	7.5	4.3	9.3	2.1	1.9	2.7	3.1
57221	do	242	16+31	♀	74	4.1	5.9	8.4	9.2	2.6	7.4	4.8	11.5	2.3	2.1	2.9	3.1
57225	do	222	17+29	♀	69	4.1	5.8	8.5	9.2	2.7	9.0	4.1	10.0	2.4	2.0	2.8	3.3
63173	Ombabika Bay	179	17+31	♂	69	4.3	5.5	9.4	8.9	2.7	7.7	4.0	8.5	2.0	2.0	2.7	3.2
63177	do	160	17+29	♂	78	4.3	5.7	10.6	8.4	2.6	8.2	4.0	8.4	2.1	2.0	2.7	3.2

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
57202	Off source of Nipigon River	4.8	3.9	2.8	4.2	2.0	3.6	4.6	2.7	2.0	2.9	1.8	1.5	11	13	12	16	1.3	0.98	8
57205	do	4.5	3.9	2.5	3.6	2.2	4.2	4.3	2.7	1.8	2.5	1.8	1.6	10	11	12	16	1.5	.95	8
57207	do	4.6	4.0	2.7	3.7	2.0	3.0	5.0	2.8	1.9	2.6	1.8	1.5	10	13	11	15	1.5	.91	8
57209	do	4.5	3.9	2.8	3.8	2.0	3.6	5.3	2.8	2.0	2.7	1.7	1.5	10	12	12	16	1.6	1.0	9
57218	do	4.4	3.7	2.8	3.7	1.9	3.4	4.7	2.7	2.1	2.7	1.9	1.5	10	12	11	17	1.5	1.0	9
57220	do	4.4	3.9	2.8	3.7	2.0	3.7	4.3	2.8	2.0	2.7	1.7	1.5	11	11	12	17	1.6	1.0	9
57221	do	4.4	4.0	2.9	3.8	2.0	3.3	5.3	2.8	2.1	2.7	1.7	1.4	10	12	12	16	1.4	1.0	8
57225	do	4.6	4.0	2.8	4.0	2.1	3.9	5.2	2.9	2.0	2.9	1.8	1.6	11	11	12	15	1.4	1.0	8
63173	Ombabika Bay	4.2	3.6	2.8	4.1	1.9	3.4	5.1	2.8	2.2	3.2	1.5	1.6	10	11	11	16	1.6	1.0	9
63177	do	4.3	3.6	2.6	3.7	2.0	3.7	5.1	2.7	2.0	2.8	1.7	1.7	10	12	12	17	1.7	.94	9

TABLE 77.—*Records of the occurrence of Leucichthys artedi in Lake Ontario*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water and character of the bottom where made, and the total number of preserved specimens examined]

Port from which nets were set	Record No.	Date	Locality	Gill-net mesh, in inches	Depth, in fathoms	Bottom	Preserved specimens examined: +225 mm.	Preserved specimens examined: −225 mm.
Winona, Ontario	1	Nov. 23, 1917		2½			12	
Bronte, Ontario	2	do		2½			11	5
	3	June 29, 1921	13 miles E. ½ S.	2½, 2¾	40-50	Mud	1	
	4	June 30, 1921	Off Oakville	4¾	16		4	1
Brighton, Ontario	5	Nov. 22, 1917	Wellers Bay				12	
	6	June 10, 1921	20 miles S. by W. of Presque Isle Light.	2½	40-50	Mud	3	1
South Bay, Ontario	7	June 7, 1921	Off the shores	3			12	
Sandy Pond, N. Y.	8	Aug. 24, 1923	9 miles west	3	25-30	Sand and mud.	45	
	9	Aug. 30, 1923	14 miles west	1½, 2½, 3, 3¼, 3½.	60	Clay	14	1
Selkirk, N. Y.	10	July 11, 1921	5 miles NNW. of Nine-Mile Point.	3	25-35	do	27	1
Oswego, N. Y.	11	Sept. 1, 1923	Off Nine-Mile Point	3	30		1	2
	12	Sept. 4, 1923	8½ miles W. by N. ½ N.	2½, 3	70-75	Clay and mud.	2	
Charlotte, N. Y.	13	July 4, 1921	7 miles off Braddock Point Light	2½, 2¾	65	Clay	1	
Wilson, N. Y.	14	July 21, 1921	2 miles north	2½	20		25	14
Borrowed specimens:								
Toronto [1]							1	
Bay of Quinte [1]							6	
Winona, Ontario [2]							28	24

[1] U. S. National Museum collection. [2] University of Toronto collection.

TABLE 78.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys artedi from Lake Ontario, half of them of the albus form from the deep water at the west end of the lake, and the rest, which are nearest the artedi form, from other areas*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
Artedi form:																	
53138	Duck Island, Ontario.	260	♂	16+32	80	4.6	6.1	10.7	8.8	2.7	9.6	3.8	7.8	2.0	2.3	3.1	3.5
53139	do	291	♀	18+32	81	4.4	6.0	10.3	10.3	2.7	8.5	4.4	9.0	2.0	2.1	2.9	3.4
53962	Wilson, N. Y.	263	♀	20+33	74	4.7	6.7	9.0	9.0	2.6	8.4	4.2	8.2	1.9	2.3	3.2	3.6
53978	do	220	♀	16+30	71	4.5	5.9	8.7	10.0	2.3	6.7	3.7	7.2	1.9	2.4	3.2	3.8
53980	do	238	♀	17+29	80	4.2	6.4	9.5	10.7	2.5	7.4	4.0	7.6	1.9	2.1	3.2	3.3
53989	do	227	♂	16+29	75	4.2	5.8	8.7	8.3	3.0	8.3	3.7	7.8	2.1	2.1	2.9	3.3
53993	do	251	♀	15+28	76	4.5	6.4	9.6	9.8	2.8	8.3	4.0	8.6	2.1	2.2	3.1	3.6
54011	Pulaski, N. Y.	294	♂	17+32	78	4.4	5.9	9.8	9.8	2.8	8.1	3.8	7.7	2.0	2.2	3.0	3.5
54020	do	286	♀	19+32	80	4.6	6.2	9.4	9.0	2.7	9.5	3.8	8.4	2.1	2.1	2.9	3.6
54023	do	300	♂	18+30	77	4.4	6.3	10.0	10.6	2.9	7.6	3.8	7.8	2.2	2.2	3.2	3.4
Albus form:																	
1172	Bronte, Ontario.	265	♀	17+31	76	4.6	6.4	9.1	9.6	2.7	7.7	3.6	7.3	2.0	2.3	3.3	3.6
1174	do	232	♂	16+29	77	4.4	6.2	8.9	8.5	2.7	9.0	3.8	7.4	1.9	2.3	3.2	3.5
1176	do	283	♀	18+30	68	4.5	6.2	8.0	9.1	2.7	7.0	3.4	6.7	1.9	2.3	3.1	3.5
1180	do	231	♀	16+28	78	4.4	6.0	9.0	9.6	2.8	7.9	3.4	6.7	1.9	2.2	3.0	3.6
1183	do	284	♀	17+28	76	4.5	6.3	8.6	8.8	2.7	8.3	3.1	7.2	2.2	2.3	3.2	3.6
1189	do	263	♀	16+30	78	4.6	6.4	9.7	9.8	2.7	8.2	3.6	6.5	1.8	2.3	3.2	3.6
1196	do	235	♂	17+30	82	4.6	6.6	9.1	8.3	2.7	7.8	3.6	7.5	2.0	2.3	3.3	3.6
1230	Winona, Ontario.	277	♀	17+33	73	4.6	6.5	9.2	10.5	2.6	7.6	3.6	6.7	1.8	2.3	3.2	3.6
1231	do	291	♀	18+31	76	4.7	6.9	8.5	9.3	2.6	8.3	3.3	6.6	1.9	2.3	3.3	3.7
1238	do	295	♀	17+31	72	4.6	6.4	8.4	10.2	2.5	8.1	3.4	6.1	1.7	2.4	3.3	3.7

TABLE 78.—*Numerical expressions of certain systematic characters for 20 specimens of Leucichthys artedi from Lake Ontario, half of them of the albus form from the deep water at the west end of the lake, and the rest, which are nearest the artedi form, from other areas*—Continued

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
Artedi form:																				
53138	Duck Island, Ontario.	4.8	4.1	2.8	4.0	1.9	3.7	4.2	3.1	2.1	3.0	1.9	1.5	10	11	11	16	1.6	0.91	8
53139	do	4.7	4.1	2.8	3.8	2.0	3.7	5.0	3.0	2.1	2.8	2.1	1.8	9	11	11	15	1.6	1.00	8
53962	Wilson, N. Y.	5.1	4.2	3.1	4.4	2.1	3.6	5.5	3.0	2.2	3.1	2.0	1.7	10	12	11	15	1.3	.86	8
53978	do	5.0	4.0	2.6	3.8	2.0	3.2	5.3	3.0	2.0	2.9	2.0	1.5	11	11	11	15	1.5	1.00	8
53980	do	5.0	4.6	3.0	4.5	-----	3.7	6.2	3.0	2.0	3.0	2.1	1.6	10	11	11	15	1.5	.98	8
53989	do	4.5	4.3	2.9	3.9	2.0	3.5	4.7	3.1	2.1	2.8	1.9	1.4	10	12	10	15	1.4	1.00	8
53993	do	5.1	4.2	2.7	3.7	2.1	3.7	4.8	3.0	1 9	2.6	1.9	1.8	10	11	12	15	1.5	1.00	7
54011	Pulaski, N. Y.	4.6	4.4	2.8	3.8	2.1	3.2	5.4	3.3	2.1	2.9	2.0	1.5	9	11	11	16	1.5	.90	9
54020	do	4.9	4.1	2.6	4.0	2.0	3.8	4.8	3.0	2.0	2.9	2.3	1.9	10	12	11	15	1.4	.91	9
54023	do	4.9	4.6	2.8	3.9	2.1	3.4	5.2	3.2	2.0	2.7	2.0	1.7	9	11	11	17	1.4	.95	8
Albus form:																				
1172	Bronte, Ontario.	5.0	4.3	2.8	4.0	2.1	3.3	5.2	3.1	2.0	2.9	2.4	1.8	10	11	11	15	1.3	.93	8
1174	do	5.0	4.3	2.6	3.7	2.0	3.7	6.3	3.0	1.8	2.6	2.0	1.5	10	12	12	16	1.4	.96	10
1176	do	4.9	4.3	2.9	3.9	2.1	4.0	5.9	3.1	2.1	2.8	1.9	1.7	12	11	11	16	1.2	.88	8
1180	do	4.9	4.3	2.7	3.9	2.0	3.3	5.8	3.3	2.0	2.8	2.3	1.8	10	10	11	14	1.4	.95	7
1183	do	5.0	4.4	2.7	3.9	2.0	2.9	5.5	3.2	2.0	2.8	2.0	1.6	10	11	11	15	1.4	.93	8
1189	do	4.9	4.6	2.7	3.9	2.0	3.2	5.4	3.4	2.0	2.8	2.1	1.7	10	11	11	16	1.4	.93	8
1196	do	5.2	4.5	2.7	3.8	2.1	3.1	5.5	3.1	1.9	2.6	1.9	1.5	9	12	11	16	1.4	.97	8
1230	Winona, Ontario.	5.0	4.4	2.8	4.1	2.1	3.2	5.2	3.2	2.0	3.0	2.1	1.8	10	12	11	15	1.3	.95	8
1231	do	5.4	4.6	2.8	4.3	2.1	3.2	5.0	3.1	2.0	3.0	2.2	1.7	10	12	11	14	1.1	.89	8
1238	do	5.2	4.5	2.9	4.2	2.1	3.2	5.7	3.2	2.0	3.0	2.0	2.0	11	10	11	17	1.3	1.00	8

TABLE 79.—*Records of the occurrence of Leucichthys nipigon in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No. [1]	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined
1	July 28, 1922	Off Macdiarmid	2½, 2¾	30	3
2	Aug. 10, 1921	Off Murchison Island		15	3
3	Aug. 15, 1922	do		25	1
4	Aug. 23, 1923	Ombabika Bay		10	2
5	June 19, 1924	do		10	8
6	July 21, 1921	Off Britannia Island			1
7	June 21, 1924	Off Caribou Island		25	2
8	Aug. 1, 1922	Grand Bay			1
9	Sept. 3, 1923	Off Gros Cap		10	1
10	July 26, 1922	Off source of Nipigon River	2½, 2¾	10–15	11
11	Aug. 15, 1922	Unknown			3
12	Oct. 26, 1922	do	4½		1
13	Aug. 18, 1923	do			1
14	[2]				6

[1] All but records 1, 8, 10, and 12 from University of Toronto collections.

[2] No data.

TABLE 80.—*Numerical expressions of certain systematic characters for the type of Leucichthys nipigon and for nine cotypes from Lake Nipigon, selected at random*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
87092[1]	Orient Bay	282	19+37	Im.♂	75	4.0	6.0	8.5	9.6	2.8	8.5	3.5	8.8	2.5	2.1	2.9	3.3
57564	do	255	21+36	Im.♂	73	4.1	5.9	8.2	8.7	2.8	7.4	3.7	9.1	2.4	2.0	2.8	3.2
N1125[2]	Ombabika Bay	336	21+38	♀	79	4.2	5.7	8.1	8.0	2.8	8.8	3.3	6.8	2.0	2.1	2.8	3.3
N1128[2]	do	346	20+36	♀	69	3.9	5.5	7.8	7.8	2.7	9.6	3.3	7.5	2.2	1.9	2.7	3.1
57212	Off source of Nipigon River.	220	20+35	Im.♂	72	3.9	5.3	8.4	8.4	2.7	8.0	3.9	9.1	2.3	1.9	2.6	3.0
57216	do	220	20+39	Im.♂	74	3.9	5.5	8.5	8.8	2.8	8.4	3.8	9.1	2.3	1.8	2.6	3.0
57219	do	221	23+39	Im.♀	82	3.9	5.5	8.1	8.9	2.8	8.5	4.1	9.6	2.3	1.8	2.6	3.0
57222	do	267	22+39	Im.♂	75	4.1	5.7	8.2	8.3	2.7	8.6	3.8	9.8	2.5	1.9	2.7	3.1
57223	do	227	20+36	Im.♀	78	4.0	5.5	8.7	8.6	2.8	7.8	4.0	8.7	2.1	1.8	2.5	3.0
57224	do	254	20+38	Im.♀	75	4.0	5.5	7.9	7.8	2.7	8.0	3.7	9.4	2.4	2.0	2.7	3.0

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	Av/V	DR	AR	VR	PR	DC	AC	Br
87092[1]	Orient Bay	4.6	4.4	2.7	3.8	2.0	3.7	5.5	3.1	1.9	2.7	1.8	1.6	10	12	12	15			8
57564	do	4.5	4.3	2.5	3.9	2.0	2.9	5.4	3.0	1.7	2.7	1.7	1.4	11	11	12	17	1.5		9
N1125[2]	Ombabika Bay	4.6	4.4	2.7	3.6	1.9	3.5	5.5	3.2	2.0	2.6	1.7	1.6	11	13	12	18	1.3	0.94	9
N1128[2]	do	4.4	4.6	2.7	3.6	2.0	3.6	5.2	3.2	1.9	2.5	1.8	1.4	11	13	12	17	1.5	.98	10
57212	Off source of Nipigon River	4.0	4.0	2.6	3.7	2.0	3.0	5.6	3.0	1.9	2.8	1.5	1.4	11	13	12	15	1.6		9
57216	do	4.2	4.2	2.6	3.7	1.9	4.0	5.6	3.0	1.8	2.7	1.7	1.5	10	12	12	16	1.5	1.0	9
57219	do	4.3	4.2	2.6	3.7	1.9	4.5	5.0	3.0	1.8	2.6	1.4	1.5	11	11	12	16	1.6	1.1	10
57222	do	4.3	4.4	2.7	3.6	2.0	3.0	6.0	3.2	1.9	2.6	1.6	1.5	10	12	12	17	1.4	.96	9
57223	do	4.1	4.2	2.5	3.7	2.0	3.2	5.0	3.1	1.8	2.7	1.6	1.6	11	11	12	17	1.6	.95	9
57224	do	4.2	4.2	2.5	4.0	2.0	3.1	6.1	3.0	1.8	2.9	1.5	1.4	11	11	13	16	1.5	.96	8

[1] Type, U. S. National Museum number. [2] University of Toronto collection.

TABLE 81.—*Records of the occurrence of Coregonus clupeaformis in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of preserved specimens examined]

Ports from which nets were set	Date	Location	Kind of net	Depth, in fathoms	Preserved specimens examined
Port Washington, Wis.	Sept. 27, 1920	Off the city	Pound	5	4
Milwaukee, Wis.	Nov. 15, 1920	20 miles ESE	2½-inch gill	28-35	1
	do	5 miles E. by S. ½ S.	do	12	10
Michigan City, Ind.	Mar. 4, 1921	15 miles NW. by N. ½ N.	do	28	4
South Manitou Island, Mich.	July 30, 1923	Off the lighthouse	Pound	3-5	22
Northport, Mich.	June 23, 1920	2 miles south	do	4	4
Traverse City, Mich.	June 22, 1920	4 miles north on east shore of West Bay	do	4	13
	July 18, 1923	Lower end of West Bay	do	5	15
	July 19, 1923	Bowers Harbor	do	5	6
	July 26, 1923	1½ miles south of Bowers Harbor	do	5	1
St. James, Mich.	July 14, 1917	Sandy Bay	do	8	2
	June 28, 1920	do	do	8	18
Charlevoix, Mich.	Aug. 11, 1923	3 miles NW. ½W.	2¾ inch gill	35-60	1
St. Ignace, Mich.	July 17, 1917	Off Gros Cap	Pound	6-10	2
Seul Choix Point, Mich.	Aug. 20, 1920	1½ miles west of Seul Choix Point	do	5-8	15
Borrrowed specimens:					
Pine, Ind.[1]					1
Edgmoor, Ind.[1]					1
Manitowoc, Wis.[2]					3
Sturgeon Bay, Wis.[2]					1
Algoma, Wis.[2]					2

[1] Field Museum collection. [2] Wisconsin Geological Survey collection.

Table 82.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Michigan, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1	St. James, Mich.	483	10+17	♀	88	5.3	6.7	8.9	9.5	2.9	6.0	3.6	7.9	2.1	2.4	3.1	4.1
10	Gros Cap, Mich.	427	10+16	Im.♂	87	5.2	6.7	9.0	9.8	2.8	6.5	3.9	8.3	2.1	2.4	3.1	4.2
2	St. James, Mich.	406	11+16	Im.♀	89	5.1	6.9	9.2	10.4	2.6	6.8	4.0	7.6	1.8	2.4	3.3	4.1
2806	do	309	10+16	Im.♀	80	4.6	6.1	8.5	9.6	2.7	7.1	3.8	7.7	2.0	2.3	3.0	3.6
2810	do	296	10+16	Im.♂	88	5.0	6.5	9.2	9.4	2.6	7.2	3.7	8.4	2.2	2.4	3.1	3.8
2815	do	293	10+16	Im.♀	88	4.8	6.6	8.4	9.7	2.5	6.5	3.7	8.3	2.2	2.3	3.2	3.7
4566	Seul Choix, Mich.	299	10+16	Im.♂	83	4.7	6.3	9.6	9.4	2.8	6.7	4.0	7.6	1.8	2.2	3.0	3.6
3728	Port Washington, Wis.	193	10+17	Im.♀	83	4.5	6.4	8.4	9.4	2.7	7.1	4.2	9.1	2.1	2.1	2.9	3.5
3731	do	204	10+15	Im.♀	81	4.7	6.3	8.8	10.3	2.8	7.0	4.3	8.8	2.0	2.2	3.0	3.7
4270	Milwaukee, Wis.	224	11+15	Im.♀	80	4.8	6.6	8.1	10.2	2.6	7.3	4.0	8.2	2.0	2.2	3.1	3.7

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt.
																					Lb. oz.
1	St. James, Mich.	5.2	5.0	3.5	3.6	2.8	1.9	10.1	4.0	2.7	2.8	2.2	1.9	11	12	11	16	1.3	1.0	10	3 11
10	Gros Cap, Mich.	5.4	4.9	3.4	3.7	2.7	2.1	11.2	3.8	2.6	2.8	2.3	2.0	11	11	11	17	1.4	1.0	8	2 4
2	St. James, Mich.	5.5	4.9	3.5	4.0	2.4	2.6	12.7	3.6	2.6	3.0	2.1	1.7	11	11	11	17	1.6	1.2	9	2 3
2806	do	4.8	4.6	3.3	3.2	2.5	2.9	11.3	3.5	2.5	2.4	1.8	1.7	11	11	11	17	1.4	1.2	9	15
2810	do	5.0	4.3	3.6	3.7	2.6	2.7	9.7	3.3	2.6	2.9	2.1	1.8	11	11	11	15	1.5	1.1	9	10.5
2815	do	5.2	4.8	3.5	3.9	2.6	2.5	10.1	3.5	2.5	2.8	2.0	1.7	12	12	11	16	1.4	1.1	9	12
4566	Seul Choix, Mich.	4.9	4.8	3.4	3.6	2.4	2.6	8.7	3.6	2.5	2.7	2.0	1.7	10	11	12	16	1.5	1.0	10	12.5
3728	Port Washington, Wis.	4.9	4.0	3.2	4.1	2.6	2.9	10.5	2.8	2.3	2.9	1.8	1.7	12	11	11	15	1.5	1.2	9	2.5
3731	do	5.0	3.9	3.4	4.0	2.6	2.7	10.2	2.9	2.5	3.0	2.0	1.7	12	12	11	15	1.5	1.1	9	3.5
4270	Milwaukee, Wis.	5.1	4.1	3.4	4.1	2.5	3.0	9.2	2.9	2.5	3.0	1.9	1.6	12	11	12	16	1.5	1.1	9	4.5

Table 83.—*Movements of the whitefish in the pound nets of Lake Michigan, according to data gathered from the operators of these nets*

Locality	Nets set	Depth, in feet	Appearance	Maximum abundance	Disappearance	Return in autumn
Port Washington, Wis.	April	20–60	June, first week	June and July	August	October, first week.
Michigan City, Ind.	April, second week	18–30	May, first week	Late May and early June.	June 15	October.
Grand Haven, Mich.	do	16–20	May, second week	July	August, first week	Do.
South Manitou Island, Mich.	June, second week	20–30	July, first week	do	do	(Nets out.)
Northport, Mich.	May, fourth week	40	September, second week.	October	October, last week	
Fox Islands, Mich.	June, second week	25–40	July, first week	July	August, first week	September, first week.
Traverse City, Mich.	May, first week	22–50	May, first week	June–July	July, last week	September, second week.
Beaver Island, Mich.	May, third week	40–45	May, third week	Late June and early July.	August, first week	September, fourth week.
Gros Cap, Mich.	June, first week	40–65	June, second week	July	July, fourth week	September, last week.
Seul Choix Point, Mich.	do	30–45	June, first week	do	August, first week	September, second week.

TABLE 84.—*Records of the occurrence of Coregonus clupeaformis in Lake Huron*

For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of preserved specimens examined]

Port from which nets were set	Date	Location	Kind of net	Depth, in fathoms	Preserved specimens examined
Lake Huron proper:					
St. Ignace, Mich	July 17, 1917	Off the city	Pound	5	1
Cheboygan, Mich	July 21, 1917	8 miles south	4½-inch gill	10–12	2
	Sept. 28, 1919	Hammond Bay	Pound	6	8
Rogers, Mich	July 24, 1917		4½-inch gill	15	3
Alpena, Mich	Aug. 13, 1917	15 miles southeast	do	10	4
	Sept. 17, 1917	13½ miles SE. by S	2¾-inch gill	15	1
	Sept. 21, 1917	Off Sulphur Island	Pound	5	3
	Sept. 22, 1917	do	do	5	10
	Sept. 24, 1917	Between can buoy and Sulphur Island	2¾-inch gill	8–10	37
	Sept. 26, 1917	13 miles SE. by S. of can buoy	do	17	4
East Tawas, Mich	Oct. 22, 1917	Off the city	Pound	4	16
Bay City, Mich	Oct. 25, 1917	Saginaw Bay	do	6	15
Providence Bay, Ontario	Sept. 29, 1919				2
Duck Islands, Ontario	Oct. 22, 1919	Off Cockburn Island	Pound	8	7
North Channel:					
Kagawong, Ontario	Nov. 10, 1917	Off Clapperton Island	do	6	4
	Oct. 16, 1919	do	do	6	7
Gore Bay, Ontario	Nov. 10, 1917	Off Barrie Island	do		4
	Nov. 12, 1917	do	do		3
	Sept. 27, 1919	do	do		10
Georgian Bay:					
Wiarton, Ontario	Nov. 5, 1917	7 miles above the city	do	4	1
	July 29, 1919	Colpoys Bay	do	4	6
	Nov. 29, 1919	do	do	4	2
Killarney, Ontario	Oct. 12, 1919		do	10	16
Borrowed specimens:					
Georgian Bay [1]					28
Bay Port, Mich. [2]					1

[1] Donated by Dr. B. A. Bensley. [2] U. S. National Museum collection.

TABLE 85.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Huron, selected according to size and locality*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
71	Cheboygan, Mich	470	♀	10+17	85	4.6	6.4	8.5	8.8	3.0	7.4	3.6	8.1	2.2	2.1	3.0	3.7
1078	Wiarton, Ontario	445	Im. ♀	11+17	76	4.7	6.5	9.3	9.5	2.8	7.4	3.5	8.0	2.2	2.2	3.0	3.7
1027	Bay City, Mich	426	♂	10+16	79	4.9	6.7	8.5	9.9	2.9	7.3	3.7	8.5	2.3	2.3	3.1	4.0
1031	do	307	Im. ♀	10+15	85	5.0	6.3	9.0	9.4	2.8	6.8	4.2	8.0	1.8	2.3	2.9	3.8
543	Alpena, Mich	307	Im. ♀	11+17	89	4.8	6.8	8.1	9.2	2.5	6.7	4.0	9.0	2.2	2.2	3.2	3.7
1936	Wiarton, Ontario	306	Im. ♂	11+17	82	4.7	6.1	8.1	9.8	2.7	7.3	4.3	8.6	1.9	2.2	2.9	3.7
2465	Killarney, Ontario	300	Im. ♀	11+17	84	4.7	6.1	9.0	9.6	2.7	6.9	4.2	8.2	1.9	2.3	3.0	3.7
1015	East Tawas, Mich	250	Im. ♀	9+17	77	4.7	6.4	9.0	9.0	2.4	6.9	3.9	8.0	2.0	2.2	3.0	3.6
1013	do	194	Im. ♂	10+16	85	4.6	6.1	8.3	9.7	2.5	6.5	4.1	7.4	1.8	2.1	2.8	3.5
980	do	201	Im. ♂	10+16	80	4.7	5.9	8.3	8.9	2.6	6.8	4.2	8.3	1.9	2.1	2.6	3.5

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/B	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt.
																					Lb. oz.
71	Cheboygan, Mich	5.1	5.3	3.4	3.8	2.6	2.8	10.2	3.8	2.5	2.5	2.0	1.8	11	12	11	17	1.4	1.0	9	
1078	Wiarton, Ontario	5.2	5.4	3.2	3.6	2.6	2.3	13.4	3.9	2.3	2.6	2.0	1.8	10	12	11	16	1.4	1.0	9	2 9
1027	Bay City, Mich	5.5	5.0	3.4	3.9	2.5	2.3	11.4	3.6	2.5	2.8	2.1	1.8	11	10	11	15	1.3	1.1	9	2
1031	do	4.4	4.5	3.2	3.7	2.7	2.7	10.1	3.5	2.6	2.9	1.8	1.7	12	12	12	16	1.5	1.1	9	13.5
543	Alpena, Mich	5.3	4.5	3.4	3.9	2.6	2.6	11.4	3.2	2.4	2.8	1.9	1.7	12	12	11	15	1.4	1.1	9	13.5
1936	Wiarton, Ontario	4.7	4.6	3.3	3.7	2.6	2.8	10.3	3.6	2.6	2.9	1.8	1.7	12	11	11	16	1.2	1.0	9	12
2465	Killarney, Ontario	4.9	4.3	3.5	3.9	2.5	2.3	9.7	3.3	2.8	3.0	1.7	1.6	11	11	11	16	1.5	1.1	9	12.5
1015	East Tawas, Mich	4.8	4.3	3.2	3.7	2.5	3.4	10.5	3.1	2.4	2.8	1.8	1.7	12	12	11	15	1.6	1.0	9	8
1013	do	4.7	4.1	3.5	4.5	2.4	2.6	10.5	3.0	2.6	3.4	1.8	1.5	11	10	11	15	1.6	1.3	9	3
980	do	4.4	4.0	3.0	3.6	2.5	2.5	10.1	3.2	2.4	2.8	1.8	1.6	11	11	11	15	1.6	1.2	9	4

TABLE 86.—*Showing the movement of the whitefish in the pound nets of Lake Huron, according to data gathered from the operators of these nets*

Locality	Nets set	Depth, in feet	Appearance	Maximum abundance	Disappearance	Return in autumn
Lake Huron proper:						
Alpena, Mich.	April, first week	26–40	May or June	June–July	August, first week	September, middle.
East Tawas, Mich.	do	25–50	June, first week	June	July, middle	September, first week.
Point Au Gres, Mich.	do	25–50	April, first week	April to May 15	June, first week	September, third week.
Port Huron Mich.	March, last week	20–30	March, last week	April	June, last week	October, third week.
Cockburn Island, Ontario.	June, last week	45	June, last week	August and September.	October, third week.	
Duck Islands, Ontario.	June, first week	30–40	do	July and August	do	
Providence Bay, Ontario.	May, first week	45–60	July, third week	August	September, first week.	October.
North Channel:						
Blind River, Ontario.	do	25	May, first week	May and June	July, third week	October, first week.
Thessalon, Ontario.	do	25	do	do	do	Do.
Gore Bay, Ontario.	June, first week	25–30	June, first week	June	July, last week	September, first week.
Kagawong, Ontario.	May, first week	35	do	June, last half	July, third week	October, third week.
Georgian Bay:						
Killarney, Ontario.	do	65–75	May, last week	June and July		
Wiarton, Ontario.	do	35–40	June, second week	June, last half	July, first week	(No fall run; mud bottom.)

TABLE 87.—*Records of the occurrence of Coregonus clupeaformis in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water and character of the bottom where made, and the number of preserved specimens examined]

Port from which nets were set	Date	Location	Kind of net	Depth, in fathoms	Bottom	Preserved specimens examined
Sault Ste. Marie, Mich.	June 14, 1922	10 miles NW. by W. ¼ W. of Point Iroquois Light.	2½ and 2¾-inch gill.	38		[1] 1
Marquette, Mich.	Feb. 8, 1921		1½-inch gill			1
	Aug. 10, 1921	Marquette Bay	Pound	5	Sand	16
Ontonagon, Mich.	Aug. 25, 1921	6 miles NNW	2½ and 2¾-inch gill.	20–38	Sand-clay	[1] 16
Apostle Islands, Wis.	July 11, 1922	Between Cat and South Twin Islands.	2¾-inch gill	15–20	Sand	1
Port Arthur, Ontario	July 20, 1922	Black Bay off Demers Point	Pound	8	Mud	34
Rossport, Ontario	Aug. 5, 1922	Moffat Strait	do	4		13
	Sept. 25, 1923	do	2½-inch gill	13–14	Clay-sand	8
Coppermine Point, Ontario.	June 24, 1922	Agawa Bay	4½-inch gill	40–50	Mud	3
Batchawanna, Ontario	June 17, 1922	Batchawanna Bay	Pound	3–13	Clay-sand	12
Borrowed specimens:						
Sault Ste. Marie, Mich.[2]						1
Port Arthur, Ontario.[3]						1
Apostle Islands, Wis.[4]						10

[1] Only specimens taken in lift.
[2] Field Museum collection.
[3] U. S. National Museum collection.
[4] Wisconsin Geological Survey collection.

TABLE 88.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Superior, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53526	Marquette, Mich.	348	10+16	Im. ♀	84	4.9	6.3	8.9	9.4	3.0	6.6	4.0	7.5	1.8	2.3	2.9	3.9
53530	do	350	11+17	Im. ♂	86	4.9	6.2	8.3	8.9	2.5	6.1	4.2	7.7	1.7	2.3	2.9	3.8
57052	Agawa Bay	380	11+17	♂	79	4.6	5.8	8.0	10.5	2.7	6.9	4.0	8.0	2.0	2.3	2.9	3.6
57362	Black Bay	278	11+17	Im. ♀	82	4.5	6.0	7.6	8.1	2.6	6.6	3.5	7.9	2.2	2.1	2.8	3.5
57366	do	271	11+16	Im. ♀	84	4.6	6.0	7.6	8.4	2.6	6.3	3.5	8.2	2.3	2.2	2.9	3.6
57381	do	297	11+16	Im. ♀	77	4.7	6.0	8.2	9.5	2.5	6.6	3.5	8.0	2.2	2.2	2.8	3.5
57840	Batchawanna Bay.	273	11+17	Im. ♂	86	4.5	5.9	8.0	7.9	2.7	7.5	4.0	9.4	2.3	2.1	2.8	3.5
53053	Marquette, Mich.	180	10+17	Im. ♀	86	4.5	6.2	8.5	9.4	2.8	6.8	4.2	10.0	2.3	2.0	2.8	3.5
53521	do	226	9+18	Im. ♂	91	4.6	5.9	8.6	9.3	2.6	6.1	4.7	9.4	2.0	2.1	2.8	3.5
53716	Ontonagon, Mich.	223	11+16	Im. ♀	84	4.6	6.2	8.7	9.2	2.7	7.9	3.8	7.9	2.0	2.1	2.9	3.8

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt.
																					Lb. oz.
53526	Marquette, Mich.	5.0	4.6	3.1	3.7	2.6	2.6	10.0	3.6	2.4	2.9	2.0	1.9	11	12	11	16	1.4	1.0	9	1 6.5
53530	do	4.8	5.0	3.4	3.9	2.7	2.6	10.2	3.9	2.6	3.1	1.9	1.7	11	11	11	15	1.4	1.0	9	1 6
57052	Agawa Bay	4.5	4.7	2.9	3.0	2.5	2.4	10.5	3.7	2.3	2.4	1.6	1.6	12	11	12	16	1.3	1.2	9	1 10.5
57362	Black Bay	4.6	4.3	3.8	4.1	2.6	2.4	10.3	3.2	2.8	3.1	1.6	1.5	11	12	12	17	1.6	1.2	9	12
57366	do	4.7	4.3	3.3	3.8	2.4	2.4	10.5	3.3	2.5	2.9	2.0	1.7	11	12	12	14	1.5	1.1	9	11
57381	do	4.5	4.7	3.6	4.0	2.5	2.4	10.1	3.7	2.8	3.1	1.6	1.6	11	11	12	16	1.6	1.2	9	13.5
57840	Batchawanna Bay.	4.5	4.4	3.3	3.9	2.5	3.1	9.6	3.4	2.5	3.0	1.8	1.5	11	13	11	15	1.5	1.0	9	8
53053	Marquette, Mich.	4.8	3.8	3.3	4.0	2.5	3.2	10.0	2.7	2.4	2.9	2.1	1.7	12	12	11	17	1.5	1.0	9	2
53521	do	4.6	4.0	3.3	3.7	2.4	2.8	8.9	3.1	2.6	2.9	1.7	1.6	11	12	11	16	1.6	1.1	10	4.5
53716	Ontonagon, Mich.	5.1	4.3	3.4	3.7	2.5	3.1	12.0	3.2	2.5	2.7	2.1	1.8	11	11	11	16	1.5	1.0	8	5.5

TABLE 89.—*Movements of the whitefish in the pound nets of Lake Superior, according to data gathered from the operators of these nets*

Locality	Nets set	Depth, in feet	Appearance	Maximum abundance	Disappearance	Return in autumn
Whitefish Point, Mich.	May, third week	24–90	June, first week	June and July	A few in August and September.	
Marquette, Mich.	June, first week	25–30	do	June and early July.	August, first week.	September, second week.
Black Bay, Ontario	do	40–50	do	Late June and early July.	do	October, first week.
Nipigon Bay, Rossport, Ontario.	May, third week	25–35	May, third week	June	July, first week	(No fall run.)
Gargantua, Ontario.	May, fourth week.	20–60	June, first week	July	August, first week.	(Nets out.)
Batchawanna Bay, Ontario.	May, third week	15–80	do	do	August, third week.	October, last week

TABLE 90.—*Records of the occurrence of Coregonus clupeaformis in Lake Nipigon*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water where made, and the total number of preserved specimens examined]

Record No.	Date	Location	Gill-net mesh, in inches	Depth, in fathoms	Preserved specimens examined
1	July 28, 1922	Off Macdiarmid	2½, 2¾	30	6
2	July 26, 1922	Off Blackwater River	2½, 2¾	1–3	3
3	Aug. 1, 1922	Ombabika Bay	4½	15–20	1
4	July 26, 1922	Off source of Nipigon River	2½, 2¾	10–15	21
5	(1)				3

[1] No data.

TABLE 91.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Nipigon, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
57251	Source of Nipigon River	206	10+17	Im.♂	86	4.3	5.4	8.5	9.8	2.8	6.4	3.9	7.9	2.0	2.1	2.6	3.4
57253	do	203	11+17	Im.♂	79	4.3	5.5	8.8	10.1	2.9	6.3	4.0	8.8	2.1	2.0	2.6	3.3
57255	do	213	11+17	Im.♀	77	4.4	5.6	9.6	9.1	2.8	6.8	3.8	9.6	2.5	2.1	2.6	3.5
57289	do	216	11+16	Im.♂	78	4.4	5.6	8.0	8.5	2.7	6.5	4.0	9.3	2.3	2.1	2.7	3.4
57328	do	212	11+18	Im.♂	89	4.4	5.7	8.5	10.7	2.7	6.4	3.9	8.8	2.2	2.1	2.4	3.3
57323	do	373	11+16	♀	79	4.8	6.1	7.9	8.8	2.6	7.3	3.3	8.1	2.1	2.2	2.8	3.5
57345	Mouth of Blackwater River	321	10+17	Im.♀	87	4.7	6.4	7.4	8.2	2.7	7.1	3.5	8.6	2.4	2.2	3.0	3.5
57346	do	328	10+17	♂	87	4.5	5.7	8.4	8.8	2.8	6.9	3.5	8.2	2.2	2.2	2.8	3.6
57598	Macdiarmid, Ontario	325	11+17	Im.♂	81	4.6	5.8	7.5	7.9	2.6	7.0	3.3	7.3	2.2	2.3	2.8	3.5
57713	Grand Bay	410	12+17	♂	84	4.3	5.5	9.0	9.0	2.8	7.7	3.8	7.4	1.9	2.1	2.6	3.4

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt.	
																					Lb.	*oz.*
57251	Source of Nipigon River	4.2	3.9	2.8	3.2	2.3	2.6	10.4	3.1	2.2	2.6	1.8	1.5	11	11	12	15	1.6	1.2	9		3.5
57253	do	4.3	3.9	3.0	3.6	2.4	2.7	11.1	3.0	2.3	2.8	1.8	1.6	10	11	11	16	1.6	1.1	9		3
57255	do	4.4	3.9	3.0	3.7	2.4	2.8	10.0	3.1	2.4	2.9	1.7	1.7	10	11	12	15	1.7	1.1	9		4
57289	do	4.4	4.0	3.1	3.9	2.4	2.5	9.0	3.1	2.4	3.0	1.6	1.4	11	13	12	16	1.6	1.1	8		4.5
57328	do	4.3	3.9	3.0	3.6	2.4	2.6	10.0	3.0	2.3	2.8	2.0	1.5	10	11	11	16	1.5	1.2	10		3.5
57323	do	4.5	4.7	3.6	3.9	2.4	2.4	11.0	3.7	2.8	3.1	1.9	1.6	11	12	11	15	1.4	1.0	9	1	11.5
57345	Mouth of Blackwater River	4.8	4.5	3.3	4.1	2.5	2.4	10.8	3.3	2.4	3.0	1.7	1.6	12	11	11	16	1.3	1.0	9		15.5
57346	do	4.5	4.2	3.2	3.9	2.4	2.3	10.2	3.4	2.5	3.1	1.6	1.5	10	12	11	16	1.5	1.1	8	1	2
57598	Macdiarmid, Ontario	4.4	4.7	3.2	3.6	2.3	2.5	11.6	3.7	2.5	2.9	1.8	1.5	11	12	11	16	1.3	1.0	9	1	3.5
57713	Grand Bay	4.4	4.8	3.1	3.3	2.4	2.8	10.1	3.8	2.4	2.6	1.6	1.6	11	12	11	15	1.4	1.1	9	2	2

TABLE 92.—*Records of the occurrence of Coregonus clupeaformis in Lake Erie*

[For each record is given, if known, the date and locality, the kind of gear used to make it, and the total number of preserved specimens examined]

Port from which nets were set	Date	Location	Kind of net	Preserved specimens examined
Monroe, Mich.	1920			2
Toledo, Ohio	Nov. 27, 1920	12 miles east	Trap	3
Sandusky, Ohio	Nov. 29, 1920	Around Bass Islands	do	5
Ashtabula, Ohio	Oct. 23, 1920	14 miles NE. by N.	4¾-inch gill	2
Erie, Pa.	Oct. 24, 1920	12 miles N. by E.	do	4
Borrowed specimens:				
Erie, Pa.[1]				1
Cleveland, Ohio[1]				1

[1] U. S. National Museum collection.

TABLE 93.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Erie, selected according to size*

[There is added also a specimen, No. 4405, of the so-called "hybrid" between the whitefish and the herring]

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
4061	Erie, Pa	402	10+15	♂	77	4.7	6.1	7.7	7.9	2.5	6.5	3.3	7.7	2.2	2.2	2.9	3.6
4065	do	382	10+18	♀	81	5.0	6.5	7.4	9.1	2.3	7.7	3.6	7.6	2.1	2.5	3.2	4.0
4066	do	369	11+17	♂	78	4.8	6.5	8.0	8.2	2.7	7.2	3.5	8.5	2.4	2.3	3.0	3.8
4059	Ashtabula, Ohio	375	11+18	♀	75	4.9	6.2	8.5	8.4	2.5	6.8	3.2	7.0	2.1	2.3	3.0	3.7
4590	Sandusky, Ohio	396	11+17	♀	85	4.8	6.3	7.9	8.2	2.7	6.3	3.8	8.2	2.1	2.3	3.0	3.6
4401	Toledo, Ohio	378	10+16	♀	81	5.0	6.4	8.0	8.4	2.6	7.8	3.4	6.7	1.9	2.5	3.1	4.0
4402	do	340	11+17	♂	80	4.9	6.0	8.6	8.0	2.7	6.5	3.4	7.9	2.2	2.3	2.9	3.8
4404	do	361	11+16	♂	77	5.0	6.2	7.8	8.8	2.7	7.0	3.6	8.0	2.1	2.4	3.0	3.9
52804	Monroe, Mich	360	11+16	♂	87	4.8	6.2	9.0	8.7	2.7	7.8	3.6	8.1	2.2	2.2	2.9	3.9
52805	do	376	10+15	♀	80	5.0	6.1	7.0	8.5	2.5	7.5	3.1	6.8	2.1	2.5	3.0	3.9
4405	Toledo, Ohio	282	14+23	♂	81	4.4	6.5	8.8	9.4	2.9	8.1	3.3	7.2	2.1	2.2	3.2	3.6

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt. *Lb.*	Wt. *oz.*
4061	Erie, Pa	4.7	5.1	3.4	3.8	2.5	2.5	9.4	3.9	2.6	2.9	1.6	1.7	11	11	11	14	1.3	1.0	9	2	9.5
4065	do	5.1	5.0	3.2	3.7	2.5	2.7	10.4	3.8	2.5	2.8	2.0	1.8	13	11	12	13	1.1	1.1	9	2	2.5
4066	do	5.1	4.9	3.3	3.6	2.6	2.6	10.1	3.6	2.4	2.6	1.8	1.5	11	12	11	13	1.5	1.1	9	1	10
4059	Ashtabula, Ohio	4.7	4.9	3.6	4.0	2.5	2.4	10.5	3.8	2.8	3.1	1.9	1.7	11	12	11	15	1.3	1.1	9	2	8.5
4590	Sandusky, Ohio	4.8	5.0	3.3	3.7	2.5	2.3	10.4	3.8	2.5	2.8	1.9	1.6	11	12	12	13	1.2	1.0	9	1	13.5
4401	Toledo, Ohio	5.0	4.8	3.3	3.5	2.6	2.4	10.4	3.8	2.6	2.7	1.9	1.6	11	11	12	14	1.3	1.0	8	2	6
4402	do	4.8	4.9	3.5	4.0	2.5	2.3	10.0	3.9	2.7	3.1	1.8	1.6	10	12	11	15	1.5	1.1	8	1	9
4404	do	4.9	4.3	3.1	3.8	2.6	2.5	10.5	3.5	2.5	3.1	1.9	1.6	11	11	12	14	1.2	1.0	9	1	11.5
52804	Monroe, Mich	5.0	4.8	3.2	3.6	2.5	3.1	10.4	3.7	2.5	2.7	1.7	1.6	11	11	11	14	1.5	1.2	8	1	9
52805	do	4.8	4.6	3.5	3.5	2.6	2.3	10.4	3.8	2.8	2.9	1.9	1.6	12	13	11	14	1.2	1.0	8	2	4.5
4405	Toledo, Ohio	5.4	4.5	3.1	4.5	2.5	2.4	6.3	3.1	2.1	3.1	1.9	1.6	10	10	11	14	1.6	1.2	9		14.5

TABLE 94.—*Records of the occurrence of Coregonus clupeaformis in Lake Ontario*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of preserved specimens examined]

Port from which nets were set	Date	Locality	Kind of net	Depth, in fathoms	Preserved specimens examined
Winona, Ontario	Nov. 23, 1917				2
Bronte, Ontario	do				2
	June 28, 1921	Off Burlington	4¾-inch gill	12	2
Port Hope, Ontario	Nov. 21, 1917				4
Brighton, Ontario	June 18, 1921	1 mile northwest of Proctor Island	4½-inch gill	5	3
Duck Islands, Ontario	June 7, 1921	Off the islands	3-inch gill		15
Cape Vincent, N. Y.	do	Off Grenadier Island	Trap		1
Sandy Pond, N. Y.	Aug. 27, 1923	Southwest of Stony Point Light	4½-inch gill	24	8
Selkirk, N. Y.	July 11, 1921	5 miles NNW. off Nine-Mile Point	3-inch gill	25–35	1
Borrowed specimens: Toronto, Ontario [1]					1

[1] U. S. National Museum collection.

TABLE 95.—*Numerical expressions of certain systematic characters for 10 specimens of Coregonus clupeaformis from Lake Ontario, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
1157	Port Hope, Ontario	444	11+16	♂	83	4.7	6.2	8.7	8.6	2.7	5.8	3.7	7.4	1.9	2.3	3.0	3.7
1158	do	423	11+16	♂	90	4.8	6.4	8.5	8.9	2.8	7.4	4.0	8.4	2.1	2.2	3.0	3.7
62435	Sandy Pond, N.Y.	415	11+17	♂	78	4.8	6.6	9.1	9.0	2.7	6.9	3.7	8.6	2.3	2.2	3.1	3.7
53258	Bronte, Ontario	407	11+17	♂	85	4.7	6.4	9.4	8.6	2.9	6.6	4.0	8.8	2.1	2.1	2.8	3.6
54049	Port Ontario, N. Y.	293	10+17	Im.♂	86	4.6	5.7	8.1	8.6	2.7	6.5	3.8	8.3	2.1	2.2	2.7	3.6
53154	Duck Island, Ontario	302	10+16	Im.♀	83	4.9	6.5	9.0	8.6	2.7	7.0	4.1	8.8	2.1	2.2	2.9	3.7
53156	do	308	11+18	Im.♀	82	4.6	6.2	8.3	8.6	2.8	6.5	4.0	7.8	1.9	2.1	2.9	3.5
53150	do	279	11+16	Im.♀	86	4.8	6.6	9.6	10.0	2.9	6.6	3.9	8.4	2.1	2.2	3.0	3.8
53155	do	253	11+18	Im.♂	79	4.5	6.0	8.0	8.4	2.6	7.0	3.8	9.3	2.4	2.1	2.8	3.4
1220	Winona, Ontario	274	10+19	Im.♂	88	4.9	6.6	9.1	9.1	2.5	6.6	3.6	7.4	2.0	2.3	3.1	3.7

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br	Wt.
																					Lb. oz.
1157	Port Hope, Ontario	4.8	5.1	3.3	3.4	2.6	2.1	10.0	3.9	2.5	2.6	1.9	1.8	11	12	11	16	1.3	0.94	9	2 14.5
1158	do	4.9	4.9	3.4	3.6	2.4	2.5	10.7	3.7	2.5	2.7	1.8	1.6	11	11	11	15	1.5	1.1	8	2 5.0
62435	Sandy Pond, N. Y.	5.2	5.0	3.7	4.0	2.8	2.6	10.7	3.6	2.7	2.8	2.0	1.7	10	12	11	10	1.4	1.0	9	2 5.0
53258	Bronte, Ontario	4.9	5.0	3.4	3.9	2.6	2.6	9.3	3.6	2.5	2.9	1.7	1.7	10	13	11	16	1.5	1.0	8	1 11.5
54049	Port Ontario, N. Y.	4.4	4.4	3.2	3.6	2.6	2.6	9.1	3.6	2.6	2.9	1.9	1.6	11	12	11	15	1.6	1.1	9	12.5
53154	Duck Island, Ontario	4.9	4.2	3.3	3.6	2.5	2.7	10.1	3.2	2.5	2.7	1.9	1.6	11	12	11	14	1.5	1.1	9	11.5
53156	do	4.8	4.4	3.3	3.6	2.7	2.7	9.4	3.2	2.5	2.6	1.7	1.4	11	12	11	16	1.5	1.1	9	14
53150	do	5.3	4.6	3.4	4.0	2.6	2.6	9.6	3.3	2.4	2.8	2.1	1.8	11	11	12	15	1.5	1.2	9	9
53155	do	4.5	4.3	3.3	4.2	2.6	2.8	11.2	3.2	2.4	3.1	1.5	1.4	11	12	11	15	1.5	1.0	9	7.5
1220	Winona, Ontario	5.0	4.5	3.3	3.7	2.6	3.0	9.1	3.4	2.4	2.7	1.8	1.8	11	12	11	15	1.5	1.0	8	10

TABLE 96.—*Records of the occurrence of Prosopium quadrilaterale in Lake Michigan*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of preserved specimens examined]

Ports from which nets were set	Date	Location	Kind of net	Depth, in fathoms	Preserved specimens examined
Washington Harbor, Wis.	Aug. 18, 1920	7 miles NNW.	2⅝-inch gill	11	1
Milwaukee, Wis.	Nov. 15, 1920	5 miles E. by S. ½ S.	2½-inch gill	12	2
Michigan City, Ind.	Nov. 19, 1920	17 miles NNW.	do	28–32	1
	do	17½ miles NW. by N. ¾ N.	do	32	2
	Mar. 4, 1921	15 miles NW. by N. ½ N.	do	28	1
Manistee, Mich.	Aug. 27, 1920	3 miles south	Pound	4	2
Platte Bay, Mich. (field station).	July 21, 1923	1½ miles south of Otter Creek	1½ gill-inch	8–12	22
	July 22, 1923	do	do	12–18	5
	do	do	do	15–25	1
	July 23, 1923	do	do	15–25	14
South Manitou Island, Mich.	July 30, 1923	Off the lighthouse	do	8–10	4
Traverse City, Mich.	June 25, 1920	4 miles north on east shore of West Bay	Pound	4	3
St. James, Mich.	June 28, 1920	Sandy Bay	do	8	3
Cheboygan, Mich.	July 23, 1917	Near Epoufette			3
Borrowed specimens:					
Algoma, Wis.[1]					3

[1] Wisconsin Geological Survey collection.

TABLE 97.—*Numerical expressions of certain systematic characters for 10 specimens of Prosopium quadrilaterale from Lake Michigan, selected according to size and locality*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
2793	Traverse City, Mich.	249	6+ 9	Im. ♀	84	5.4	7.1	9.3	13.2	2.4	6.5	4.6	8.8	1.8	2.3	3.0	4.0
2797	Beaver Island, Mich.	324	7+11	♂	89	5.1	6.5	9.8	13.6	2.7	7.4	4.7	7.5	1.5	2.2	2.8	4.0
2800	do.	341	8+11	♂	92	5.4	7.1	8.7	11.9	2.3	6.9	4.3	7.2	1.6	2.2	2.9	4.0
3101	Washington Harbor, Wis.	232	6+11	Im. ♀	94	5.2	7.0	8.6	12.8	2.5	7.0	5.5	8.5	1.5	2.2	3.0	3.9
4280	Milwaukee, Wis.	254	7+10	Im. ♀	87	5.5	7.1	10.3	14.1	2.4	5.9	5.0	7.9	1.5	2.3	3.0	4.1
4284	do.	256	7+11	Im. ♀	92	5.3	6.9	10.4	15.2	2.6	5.9	5.4	8.0	1.4	2.3	3.0	4.0
4392	Michigan City, Ind.	295	7+10	♂	88	5.4	7.2	9.4	12.2	2.4	6.5	5.0	9.5	1.8	2.3	3.0	4.1
4396	do.	293	6+10	Im. ♀	95	5.4	6.9	9.7	13.4	2.3	6.1	4.8	8.1	1.6	2.4	3.0	4.1
3373	Manistee, Mich.	299	7+ 9	Evis.	90	5.2	6.8	9.5	13.0	2.5	6.6	5.3	8.3	1.5	2.2	2.9	4.0
4639	Michigan City, Ind.	270	7+10	Im. ♀	89	5.2	7.1	10.0	13.5	2.4	6.5	5.4	7.9	1.4	2.2	3.0	4.1

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
2793	Traverse City, Mich.	5.3	4.3	4.2	4.1	2.8	3.0	20.9	3.3	3.2	3.1	2.0	2.2	11	10	10	14	1.2	1.4	8
2797	Beaver Island, Mich.	5.0	4.3	4.1	3.7	2.8	3.1	28.4	3.4	3.3	2.9	2.1	2.2	11	9	11	16	1.3	1.3	7
2800	do.	5.3	4.5	3.8	4.1	2.9	2.8	21.0	3.4	2.9	3.1	2.1	2.2	12	11	11	16	1.2	1.2	8
3101	Washington Harbor, Wis.	5.3	4.1	4.6	4.4	2.9	2.9	22.0	3.1	3.4	3.3	2.0	2.3	12	11	11	15	1.1	1.4	8
4280	Milwaukee, Wis.	5.4	4.5	4.1	4.1	3.0	2.8	23.0	3.4	3.2	3.2	2.1	2.3	11	9	10	16	1.4	1.5	7
4284	do.	5.2	4.4	4.7	3.9	2.8	2.8	24.0	3.4	3.6	3.0	2.0	2.1	12	9	11	14	1.4	1.6	8
4392	Michigan City, Ind.	5.4	4.5	4.2	4.0	3.3	2.8	24.5	3.4	3.1	3.0	2.2	2.1	12	11	11	14	1.3	1.3	7
4396	do.	5.2	4.7	4.5	3.7	3.1	2.8	24.3	3.7	3.5	2.9	2.2	2.3	13	10	11	15	1.3	1.4	7
3373	Manistee, Mich.	5.3	4.4	4.6	3.7	3.1	2.9	26.1	3.3	3.4	2.8	2.0	2.3	12	10	11	16	1.3	1.3	7
4639	Michigan City, Ind.	5.5	4.5	4.3	4.0	2.9	2.8	23.1	3.3	3.2	3.0	2.2	2.2	11	10	11	15	1.4	1.4	8

TABLE 98.—*Records of the occurrence of Prosopium quadrilaterale in Lake Huron*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of the water, and the total number of specimens examined]

Port from which nets were set	Date	Location	Method of capture	Depth, in fathoms	Preserved specimens examined
Lake Huron proper:					
St. Ignace, Mich.	July 17, 1917	Off the city	Pound net	4	4
Cheboygan, Mich.	July 21, 1917	8 miles south	4½-inch gill net		1
Alpena, Mich.	Sept. 10, 1917	13½ miles SE. by S. of can buoy	do	15	2
	Sept. 14, 1917	24 miles SE. by E. ½ E. of can buoy	do	24	2
	Sept. 17, 1917	13½ miles SE. by S. of can buoy	2¾-inch gill net	15	5
	Sept. 20, 1917	On north grounds	4½-inch gill net	10–12	1
	Sept. 22, 1917	15 miles SE. by S. ½ S. of can buoy	do	17	1
	Sept. 26, 1917	13 miles SE. by S. of can buoy	2¾-inch gill net	17	1
	Nov. 2, 1917	7 miles ENE. of can buoy	do	15	41
	Nov. 15, 1919		do	15	40
Duck Islands, Ontario	Oct. 18, 1919	Off Greater Duck Island	Hand line	2	34
North Channel:					
Blind River, Ontario	Oct. 6, 1917	Off Grant Island	4½-inch gill net	3–5	6
Gore Bay, Ontario	Nov. 7, 1917	Off Barrie Island	Pound net	5	2
Kagawong, Ontario	Nov. 10, 1917	Off Clapperton Island	do	6	3
	Oct. 16, 1919	do	do	6	2
Georgian Bay:					
Wiarton, Ontario	Nov. 5, 1917	7 miles above the city, in Colpoys Bay	do	4	6
Killarney, Ontario	Oct. 10, 1919	Off the city	do	10	1

TABLE 99.—*Numerical expressions of certain systematic characters for 10 specimens of Prosopium quadrilaterale from Lake Huron, selected according to size and locality*

Field No.	Locality	Length	Sex	Rakers	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
19	St. Ignace, Mich	276	♀	6+10	84	5.3	6.7	9.5	11.0	2.5	6.8	4.8	8.6	1.7	2.3	3.0	4.1
69	Cheboygan, Mich	300	♂	8+10	87	5.0	6.7	9.0	13.1	2.5	7.3	4.7	7.5	1.5	2.1	2.9	3.9
222	Alpena, Mich	245	Im. ♂	5+11	86	5.0	6.5	9.6	12.1	2.5	7.2	5.5	8.4	1.5	2.1	2.8	3.9
330	do	241	Im. ♀	8+11	93	5.2	6.7	9.4	13.0	2.5	6.8	4.9	8.6	1.7	2.2	2.9	4.0
431	do	288	♂	6+11	90	4.8	6.6	8.8	12.5	2.5	7.2	5.0	7.4	1.4	2.1	2.8	3.9
1070	Wiarton, Ontario	295	♀	6+11	88	5.2	6.8	8.9	10.8	2.5	7.7	4.7	7.6	1.6	2.3	3.0	4.0
1104	Kagawong, Ontario.	316	♀	7+11	89	5.1	7.1	9.0	13.3	2.4	7.0	4.4	7.0	1.5	2.2	3.1	4.0
1096	Gore Bay, Ontario.	363	♀	6+10	88	5.2	7.2	9.1	11.0	2.4	6.0	4.1	6.8	1.6	2.2	3.1	4.1
2497	Duck Islands, Ontario.	276	♂	5+11	89	5.0	6.5	8.7	13.1	2.5	7.4	4.8	8.4	1.7	2.2	2.8	3.9
2519	do	255	♂	5+10	90	5.0	6.6	9.1	12.7	2.5	7.9	5.2	8.6	1.6	2.2	2.9	3.9

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
19	St. Ignace, Mich	5.3	4.3	4.4	3.5	2.9	2.9	26.0	3.4	3.4	2.8	1.9	2.4	11	10	11	16	1.3	1.2	7
69	Cheboygan, Mich	5.3	4.6	4.2	3.7	2.8	3.3	-----	3.4	3.1	2.7	1.9	2.3	12	10	11	16	1.2	1.3	7
222	Alpena, Mich	5.1	4.0	4.0	3.8	3.0	3.5	24.5	3.1	3.1	2.9	2.0	2.2	11	10	11	15	1.3	1.3	7
330	do	5.2	4.1	4.6	3.5	3.0	3.2	22.7	3.2	3.6	2.7	2.0	1.9	12	10	11	15	1.2	1.4	7
431	do	5.2	4.4	4.0	3.9	3.1	3.2	26.8	3.2	3.0	2.9	1.9	2.4	11	10	11	16	1.2	1.3	8
1070	Wiarton, Ontario	5.3	4.5	4.1	3.6	3.0	3.1	25.6	3.4	3.1	2.7	2.0	2.0	12	11	11	18	1.2	1.2	7
1104	Kagawong, Ontario.	5.5	4.5	4.3	3.9	3.0	2.1	27.9	3.2	3.1	2.8	2.1	2.2	11	10	12	16	1.2	1.6	8
1096	Gore Bay, Ontario	5.6	4.9	4.0	3.7	2.8	2.7	23.0	3.5	2.9	2.7	2.0	2.3	11	10	10	16	1.2	1.2	8
2497	Duck Islands, Ontario.	5.1	4.2	3.9	3.8	2.7	3.6	25.0	3.2	3.0	2.9	2.0	2.2	11	10	10	15	1.2	1.3	7
2519	do	5.1	4.2	4.1	4.1	2.9	3.4	25.5	3.1	3.1	3.1	1.8	2.2	11	11	11	16	1.3	1.3	7

TABLE 100.—*Records of the occurrence of Prosopium quadrilaterale in Lake Superior*

[For each record is given, if known, the date and locality, the kind of gear used to make it, the depth of water, and the number of preserved specimens examined]

Port from which nets were set	Date	Location	Method of capture	Depth, in fathoms	Preserved specimens examined
Port Arthur, Ontario	July 20, 1922	Black Bay	Pound net	8	5
Porphyry Island, Ontario	Sept. 19, 1923	Off shore	Hand line	1	1
Rossport, Ontario	Oct. 1, 1921	Off the town	2¾-inch gill net	6	14
	Oct. 4, 1921	Les Petits Ecrits	Hand line	1	3
	Aug. 10, 1922	Moffat Strait	Pound net	4	1
	do	Armour Point	do	4	1
	do	Morn Point	do	4	1
	Sept. 25, 1923	Armour Harbor	4½-inch gill net	2	1
	do	Moffat Strait	2½-inch gill net	13–14	7
Batchawanna, Ontario	June 17, 1922	Batchawanna Bay	Pound net	8	1
Stannard Rock Reef	Aug. —, 1923	On the reef			1
Apostle Islands, Wis	July 12, 1922	South Twin Island	2¾-inch gill net	4	31
Grand Marais, Minn	July 17, 1922	Devils Track River	Seine	1	11
	July 18, 1922	In the harbor	do	1	6
Borrowed specimens:					
Lizard Islands, Ontario [1]					5

[1] Field Museum collection.

TABLE 101.—*Numerical expression of certain systematic characters for 10 specimens of Prosopium quadrilaterale from Lake Superior, selected according to size*

Field No.	Locality	Length	Rakers	Sex	Scales	L/H	L/O	L/DB	L/AB	L/DA	L/AT	L/D	L/W	D/W	SD/H	SD/O	SA/H
53839	Rossport, Ontario	301	7+10	♀	84	5.1	6.7	8.3	14.1	2.4	7.0	4.1	7.7	1.8	2.2	2.8	4.2
53841	do	377	7+10	♀	87	5.2	6.7	9.3	11.6	2.5	8.1	4.6	7.8	1.6	2.3	3.0	4.1
53842	do	292	7+12	♂	90	5.1	6.4	8.6	12.5	2.5	7.1	4.3	7.3	1.6	2.2	2.8	4.0
53848	do	323	7+10	♂	91	5.0	6.3	7.9	11.0	2.5	6.8	4.8	8.0	1.6	2.2	2.7	3.8
53850	do	286	7+10	♀	74	5.0	6.5	8.1	11.6	2.5	7.7	4.4	7.5	1.6	2.2	2.9	3.8
58020	Apostle Islands, Wis	256	8+10	♀	86	5.0	6.0	9.0	12.8	2.6	7.3	5.6	8.5	1.5	2.2	2.7	3.9
58021	do	277	7+10	♀	90	5.0	6.5	8.7	11.5	2.6	8.1	5.2	7.1	1.5	2.1	2.8	3.9
58023	do	236	8+11	♀	97	4.9	7.1	8.1	11.1	2.5	7.1	4.8	7.1	1.4	2.1	2.8	3.8
58027	do	277	7+10	♂	93	5.0	6.2	7.7	11.6	2.4	6.7	5.0	8.1	1.6	2.1	2.7	3.9
58042	do	245	7+ 9	♂	86	4.9	6.5	9.6	11.5	2.6	6.9	5.4	8.4	1.5	2.1	2.9	3.8

Field No.	Locality	SA/O	H/E	H/M	H/S	H/J	H/Ad	H/R	O/E	O/M	O/S	PV/P	AV/V	DR	AR	VR	PR	DC	AC	Br
53839	Rossport, Ontario	5.5	4.7	4.2	3.6	2.8	3.2	20.7	3.6	3.2	2.7	1.9	2.3	12	9	11	16	1.2	1.5	7
53841	do	5.4	5.1	4.2	3.8	3.1	3.1	25.8	3.9	3.2	2.9	1.8	2.2	12	11	11	16	1.3	1.3	7
53842	do	5.0	4.6	4.0	3.7	2.9	3.5	25.9	3.7	3.2	2.9	2.0	2.3	11	10	11	17	1.2	1.3	7
53848	do	4.8	4.6	4.0	3.7	3.0	2.9	22.8	3.6	3.2	2.9	1.6	2.0	13	10	11	17	1.2	1.3	8
53850	do	5.0	4.3	3.9	3.7	2.9	4.3	25.9	3.3	2.8	2.8	2.0	2.2	12	10	11	14	1.1	1.2	7
58020	Apostle Islands, Wis	4.8	4.2	4.2	3.6	2.8	3.2	23.1	3.5	3.5	3.0	1.8	2.2	12	10	11	16	1.2	1.4	7
58021	do	5.1	4.2	4.0	3.9	2.9	3.4	19.6	3.2	3.1	3.0	1.8	2.2	12	11	11	16	1.3	1.3	7
58023	do	4.9	4.2	4.0	3.7	2.7	2.9	21.8	3.3	3.1	2.8	1.8	2.0	12	10	11	16	1.1	1.2	7
58027	do	4.8	4.2	4.2	3.8	2.8	3.0	27.2	3.4	3.4	3.1	1.9	1.9	12	10	11	15	1.2	1.4	7
58042	do	5.0	4.1	4.8	4.0	2.9	3.0	22.7	3.1	3.6	3.0	1.7	2.0	12	11	11	16	1.4	1.3	7

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GENERAL INDEX